This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

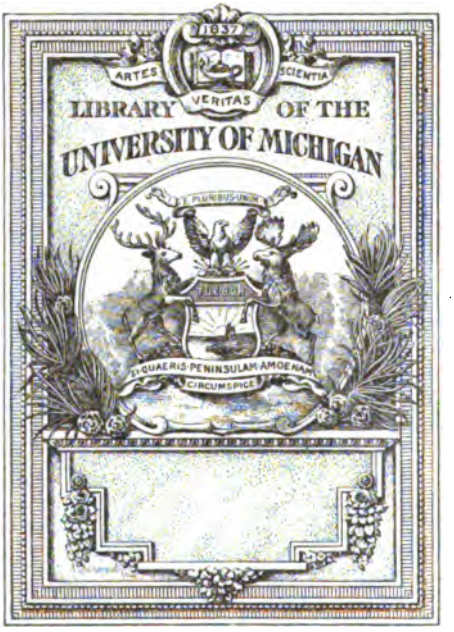
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`


1837
ARTES
SCIENTIA
VERITAS
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE

Astron.
Obs.
QB
1
.R883

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

G25-06

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1894 *TO NOVEMBER* 1895.

VOL. LV.

LONDON:
ROYAL ASTRONOMICAL SOCIETY
BURLINGTON HOUSE, W.
1895.

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
LONDON

617 8

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. NOVEMBER 9, 1894. NO. 1

Captain W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S, President, in the Chair.

Major Archibald S. Drummond, Guards' Club, Pall Mall, S.W., and 117 Ashley Gardens, S.W.;
S. Maitland Baird Gemmill, care of W. L. Wilson, 254 St. George's Road, Glasgow; and
Samuel Arthur Saunder, M.A., Wellington College, and Fir Holt, Crowthorne, Berks,

were balloted for and duly elected Fellows of the Society.

Professor Albert A. Michelson, University Chicago, U.S.A.; and
Professor H. Poincaré, à l'Institut, Paris,

were balloted for and duly elected Associates of the Society.

The following candidates were proposed as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

J. J. Aubertin, 33 Duke Street, St. James', S.W. (proposed by Sir R. S. Ball);
Charles Josephus Greene, M.R.C.S., L.S.A., 10 St. Paul's Square, Preston, Lancashire (proposed by R. Wilding);
Frederic Hammond, F.R.I.B.A., Architect, 2 Mercers Road, Tufnell Park, N. (proposed by J. I. Berry);

William Harnett, Cullentra, Wimbledon Park, S.W. (proposed by John Browning);

Rev. Thomas Roseby, M.A., LL.D., The Parsonage, Marrickville, Sydney, New South Wales (proposed by R. T. A. Innes);

Rev. Peter Hately Waddell, M.A., B.D., The Manse, Whitekirk, East Lothian, Scotland (proposed by William Peck); and

Robert Wigglesworth, York (proposed by A. A. Common).

One hundred and eighty-four presents were announced as having been received since the last meeting, including amongst others:—

A series of sixty-one transparencies from negatives of Comets, Milky Way, &c., taken at the Lick Observatory, presented by E. E. Barnard; S. W. Burnham, double star observations made with the 36-inch equatorial of the Lick Observatory, presented by the author; Cape Observatory, heliometer observations for determination of stellar parallax, presented by the Observatory; A. Cayley, Collected Mathematical Papers, vol. vii., presented by the author; Cordoba Durchmusterung Catalogue and Atlas, presented by the Observatory; a series of enlargements of photographs of the Moon, &c., and original negatives of *Jupiter* and *Saturn*, taken by the late Warren de la Rue, presented by Mr. Ernest de la Rue; H. Deslandres, Collection of Papers, presented by the author; J. L. E. Dreyer, Observations of Nebulæ, presented by the author; J. G. Galle, Verzeichniss der Elemente der Cometenbahnen, presented by the author; S. Glasenapp, Observations Astronomiques faites à Abastouman, presented by the author; Greenwich Observations, 1891, presented by the Observatory; J. E. Keeler Spectroscopic Observations of Nebulæ made at the Lick Observatory, presented by the author; Laplace, Œuvres Complètes, tome x., presented by the Paris Academy; Publications of the Lick Observatory, vols. ii. and iii., presented by the Observatory; two photographs of the eclipse of 1893 April, presented by Comte de la Baume Pluvinel; enlargements of lunar photographs, presented by W. Prinz; Radcliffe Catalogue of 6,424 stars, presented by the Radcliffe Trustees; A selection of photographs of stars, star clusters and nebulæ, by Isaac Roberts, presented by the author; a box of lantern slides, presented by Dr. Roberts; Robertson, Sectionum Conicarum libri vii., with MS. notes by F. Baily, presented by E. B. Knobel; The Collected Mathematical Papers of H. J. S. Smith, edited by J. W. L. Glaisher, 2 vols., presented by the delegates of the Clarendon Press; Webb's Celestial Objects, new edition, vol. ii., presented by the publishers; Wilson and Gray, Investigations on the effective Temperature of the Sun, presented by the authors.

Note on Mr. Stone's Theory of the Measure of Time.

By Professor Simon Newcomb.

The discussion with Mr. Stone has now reached a stage where nothing remains to be done on my part except to invite Mr. Stone's attention to the conclusions from his theory, as he states them in the May number of the *Monthly Notices*.

A copy of Le Verrier's *Tables du Soleil* has been in my possession since the year 1859. If, with the tables in this book, I compute the sidereal time of mean moon on 1892, January 6, and thence the tabular right ascension of the Moon from Hansen's tables at the moment of its transit over the meridian of Oxford, on that date, I find a difference between the tabular and observed right ascension of $1^s.36$. The result will be substantially the same if I use the older tables of Carlini.

Mr. Stone maintains that this result is due to my failure to apply a certain correction to the numbers of Le Verrier's tables, which correction is not a function of anything contained in the tables, or of the epoch of any natural event, but of the date when a certain office, three thousand miles away, began to use the tables in computing the solar ephemeris. In his last note on the subject he gives precision to this conclusion by stating explicitly that if the office in question had not begun the use of the tables until 1892, the result would have been $0^s.10$, instead of $1^s.36$. The statement is still further strengthened by his answer to my second question, that $0^s.10$ would also have been the result if Carlini's tables had been continued to the present time in the *Nautical Almanac* Office, though, if I make the computation with Carlini's tables *now*, I shall get nearly $1^s.36$, the same as with Le Verrier's tables. It thus seems, according to Mr. Stone's theory, that the results which I now get from tables are different from what they would have been had a change of tables not been made in the *Nautical Almanac* Office.

Note on the Lunar Theory. By Professor Ernest W. Brown, M.A.

The terms in Delaunay's expression for the longitude with arguments $2iD \pm l \pm l'$ (i a positive integer), and coefficients of the form $ee'f(m)$ converge in some cases very slowly as far as the series arranged in powers of m are concerned. I have lately calculated the terms of this form, and have obtained the results exhibited in Column II. of the table given below. The values given have been carefully verified, and are correct to the fourth place of decimals of a second :—

I. Argument.	II. B.	III. D.	IV.	V.	VI. B−D.
	"	"	"		"
$l+l'$	−110·1758	−110·1358	−0·1213	$\frac{1}{33}$	−0·0390
$2D-l-l'$	+206·8242	+207·0770	−0·3488	$\frac{2}{3}$	−0·2528
$4D-l-l$	+ 4·0861	+ 4·0312	+0·2074	$\frac{1}{3}$	+0·0549
$6D-l-l$	+ 0·0545	+ 0·0188	+0·0183	...	+0·0357
$8D-l-l'$	+ 0·0006	...	...	...	...
$2D+l+l'$	− 2·6612	− 2·6670	−0·0168	$\frac{2}{9}$	+0·0058
$4D+l+l'$	− 0·0370	− 0·0290	−0·0146	...	−0·0080
$6D+l+l'$	− 0·0004	...	...	...	...
$l-l'$	+149·1996	+148·3768	+0·8490	$\frac{1}{1}$	+0 8228
$2D-l+l'$	− 27·8714	− 29·2689	+1·4294	$\frac{1}{2}$	+1·3975
$4D-l+l'$	− 0·5780	− 0·7446	−0·0178	$\frac{1}{2}$	+0·1666
$6D-l+l'$	− 0·0078	− 0·0040	−0·0040	...	−0·0038
$8D-l+l'$	− 0·0001	...	...	...	...
$2D+l-l'$	+ 13·6294	+ 13·6278	+0·1526	$\frac{2}{6}$	+0·0016
$4D+l-l$	+ 0 2160	+ 0·1722	+0·0717	$\frac{3}{4}$	+0·0438
$6D+l-l'$	+ 0·0027	...	...	...	...

The columns numbered I.–VI. are as follows :—

I. The arguments in Delaunay's notation.

II. The results of my calculations. (These are obtained by using the numerical values of m from the start and inserting Delaunay's values of e and e' at the finish.)

III. Delaunay's values for the portions of the form $ee'f(m)$ as given in vol. xxix. of the *Memoirs of the French Academy of Sciences* on pp. 804, 805, 818, 819, 822, 823, 838, 839, 845, 846.

IV. The values of the last terms of the series in powers of m calculated by Delaunay to obtain the values in III.

V. The approximate ratio of the last group of terms of the same sign in Delaunay's series in powers of m. (See below.)

VI. The differences between columns II. and III.

Column V. is of importance as showing how an estimate can be made for the neglected terms in Delaunay's series. The series for any coefficient in the longitude all appear to have a common property which seems to be worth emphasising. In any coefficient we can pick out the terms of the form

$$e^i e'^j \gamma^p (a/a')^q (a_0 + a_1 m + a_2 m^2 + \ldots)$$

where

$$a_0, a_1, a_2 \ldots$$

are the positive or negative numerical multipliers. Then, in

nearly all cases, it will be found that (1) a series of the numbers,

$$a_0, a_1, a_2 \ldots a_r,$$

are of the one sign, followed by another series,

$$a_{r+1} a_{r+2} \ldots a_s,$$

of the opposite sign, again followed by a third series,

$$a_{s+1}, a_{s+2} \ldots a_t,$$

of the first sign, and so on; the first change of sign may occur anywhere, but there are generally five or six terms at least before the sign changes again. (2) Whatever law governs these series, the natural result follows that the numerical multiplier on either side of the new sign is very small. (See *Monthly Notices*, vol. lii. p. 74.) (3) The terms of the series forming a group of the same sign have approximately a common ratio. Hence, if one of Delaunay's series has an approximately common ratio for the later terms, and if, in addition, the last term given do not fall in with this ratio, but is very small, we can accept it as very probable that the next term will be of the opposite sign, and can estimate the rest of the series accordingly.

A single example will illustrate these points, and will explain the only apparent discordance between my results and those of Delaunay as given in the table above. This is the coefficient of the term with argument $4D - l + l'$. Expressed in seconds, this coefficient is—

Term in $ee'm^2$	$-0''.4750$
„ „ $ee'm^4$	-0.2518
„ „ $ee'm^5$	-0.0178
Sum	-0.7446
My coefficient being	-0.5780
Value of the rest of Delaunay's terms	$+0.1666$

showing that the terms must change sign.

The most important results are those for the coefficients of the terms with arguments $l - l'$ and $2D - l + l'$. The results show that an estimate with the common ratio $\frac{1}{2}$ would have given nearly the correct result.

Christ's College, Cambridge,
1894 October 27.

Notes on Solar Observations at Stonyhurst College Observatory.
By the Rev. W. Sidgreaves.

Drawings of Sun-spots and Faculæ.—In the summer of 1891 an arrangement was made for a tentative examination of the collection of drawings of Sun-spots and faculæ; with the object, primarily, of ascertaining whether it could be considered probable that any trustworthy improvement might be made upon Carrington's measures of solar rotation; and, secondarily, of estimating by the experience of one year the labour of dealing with the work of a dozen.

For this purpose the period of least spot frequency—the year 1889—was selected, as offering a field of inquiry comparatively free from the entanglement of old with new growths. It was hoped that a careful study of the behaviour of the several groups both of spots and of faculæ during their lifetimes might lead to some systematic selection of least wandering landmarks that would be independent of that personal estimation of their stability necessarily employed by Mr. Carrington.

The reductions have been executed with extreme care by Mr. W. McKeon, to whom we are indebted also for nearly all the drawings made during the lifetime of the late Father Perry. The work was finished, after numerous interruptions, at the end of 1893. It contains complete tabulations of the heliographic positions of spots and faculæ, and of their deduced diurnal motions, seventeen charts of mean positions (including the winter months of the preceding year), four charts of daily positions, two charts of distribution in latitude, and one of "recurrences."

The heliographic positions have been read off the drawings by means of a transparent disc projection of the hemispherical lines of latitude and longitude, which has been carefully tested by comparison with the recorded positions of spots in the Greenwich Catalogues, and has been found to give the Greenwich measures within 0°·01 of longitude and 0°·10 of latitude.

The table of diurnal motions shows that the erratic movements of spots, even after the first commotions of formation have subsided, are so great that only a very long series of observations could be trusted for an amendment to the adopted period of the solar rotation. The slower rotation in higher latitudes, first noted by Scheiner in 1630, is clearly indicated; but Carrington's law of this variation is hardly perceptible. Carrington also drew attention to the recurrence of spots in the same position. This tendency has been since observed by Secchi, Perry, and Maunder,* and we find it well marked in the year 1889. The chart of recurrences shows eight distinct regions where spots have reappeared after extinction, but we find no indication of per-

* *Le Soleil*, tome i. p. 142; *Astron. Register*, 1884 November, p. 252; *Monthly Notices of R.A.S.*, vol. l. p. 362.

manency in these regions—nothing to mark an area on the solar map as an irruptive region corresponding to our volcanic countries on Earth. They are, however, indicative of a more enduring state of disturbance than is measured by the lifetime of a single spot, for it is not improbable that a recurrence springs from the same source as its predecessor. And if this be true, the spots must be more subject to drift than their underlying origins, for nearly always the recurring spot is found to the rear of the former position.

The brighter patches of matter, known technically as faculæ, have been the more carefully studied since they were not included by Carrington in the work imposed upon himself. They have been treated in every way according to his method of estimating the motions of spots. Their greater extent of surface and their greater length of duration add much to the difficulty of identification at their several reappearances with the solar rotation. This is possible and comparatively easy at the minimum period; but at times of greater solar activity the several groups of faculæ would become too entangled for separate treatment. On this account it would seem a hopeless task to measure the solar rotation by the motion of faculous groups at any other than the minimum period; and no attempt has been made to carry on the work beyond the year 1889, although the results of this year show favourably in comparison with those obtained from the spots, and prove that the uncertain fixity of an adopted centre of a group is more than compensated by its much longer span of life. The average duration of a group of faculæ in 1889 was five times that of the companion spot.

The tabulated heliographic positions of the faculæ show that these are roughly subject to the same law of rotation-change as the spots. But the question of "lagging" seems to be left open. The appearances on the charts of faculæ and spots are decidedly in favour of the faculæ falling behind the spots in their march across the solar disc. Mr. McKeon, who has had the advantage of continous observation of the solar surface while sketching the spots and faculæ, is of opinion that there is no real change in the relative positions of the two: that the appearance is only the result of the previous extinction of the following member of a double spot, which has left its retinue of faculæ as attendants on the surviving and leading spot. In this way the survivor is left well to the front of a large group of faculæ, with the appearance of heading its way out of their midst. There can be no doubt that this history of the group robs the picture of the major part of the first-sight impression of lagging faculæ; but when all allowance has been made for the extra appendages to the surviving spot, there is—to the writer, at least—some evidence in favour of a real falling back of the group of faculæ. But it is not clear whether this has been a gradual retardation, or whether it is to be attributed wholly to the leap forward of the leader, so often observed in the first days of a twin spot group.

The following table will serve to show the degree of probability we have for asserting that faculæ in general drift with the spots. Of the thirteen groups observed in the period, two were found in North Latitude at 5° and 7°, and all the rest appeared south of the Equator—viz. one at 2°, one at 3°, four at 8°, three at 9°, and two near 25°.

Mean Latitude.	No. of Groups.	Extreme Difference of Diurnal Motion.	Mean Diurnal Motion.	Carrington's No. for Spot Motion.
− 3°	2	8′	+15′	+13′
+ 6	2	8	+11	+11
− 9	7	32	+19	+ 8
−25	2	5	−13	−23

There is a very marked difference of motion indicated for the higher latitude; and it is sufficiently in accord with Carrington's law for the spots to warrant the conclusion that a great number of observations would establish, in general, the same law for both faculæ and spots. An extensive investigation of this nature might also result in a differential law for the two motions; for it cannot escape notice that the table shows nearly uniformly an accelerated drift of the faculæ as compared with Carrington's numbers obtained from the motions of spots.

The outline history of a group of spots and faculæ, as learned from the study of twenty-seven groups of 1889, may be given in a few words. First a few bright faculæ appear; in a day or two one or more black dots are seen in their midst; these rapidly increase along with the faculæ, and attain their full growth in about five or six days, while the faculæ continue to grow with the waning of the spot till they attain their fullest development at the extinction of the spot. At this epoch they begin to extend over a large area, steadily losing their lustre and falling off piece by piece, notwithstanding the frequent rekindlings amongst them by small newly-formed spots.

Of the parts of the outline history of a spot, the circumstances attending its birth are, no doubt, of the first interest in the connection of facts with theoretical explanation. The prior appearance of faculæ has been already noted in a communication to the *Monthly Notices* of 1891 December, where a full account was given of the nature of the evidence afforded by our drawings at this minimum period of solar activity. Further evidence was discovered later, and mentioned in the Report of the Council in 1893 February. And since then three other spots have been added to the list, making a total of nine observations of spots preceded by small bright faculæ. For six of these the evidence of precedence is complete, and for the remaining three only wanting as to the certainty of the complete extinction of the faded remains of a former group.

In the same report of 1893 February it was noted that two remarkable polar belts of small short-lived faculæ, unassociated with spots, appeared on the charts in latitudes 72° north and south. These deserve the additional remark of the observer that they were too clear to escape notice, although of less intensity than those of the lower belts, and left no doubt upon his mind of their reality. The extensive regions of faculous matter shown on the photographs at Paris and Chicago have led us to doubt whether the photographic charts will agree with our drawings in this respect. But we think that the marked way in which these little patches have caught the eye must claim for the high-latitude zones a distinctive character at the minimum period.

Photographic Plates of the Spectra of Sun-spots and Faculæ.—Our method of photographing the spectra of spots has been described in the *Monthly Notices* of 1893 February. We found after some experience with the enlarging lens mentioned in the same paper that the amount of light supplied by the double reflection from the two small mirrors of the heliostat was not enough for the enlarged image of a spot. The exposure became too long, and it was practically impossible to keep the spot sufficiently stationary on the slit for a satisfactory photograph. Our collection, therefore, of photographic plates of the spectra of sun-spots and faculæ has the disadvantage of showing only a very small band for examination; and we give the results rather as suggestions seeking correction or confirmation from better instruments than as facts established by our observations.

1°. Our plates of the yellow and green regions afford no trustworthy evidence of absorption lines widening over spots. There is, no doubt, an appearance of widening where the spot band crosses the spectrum, both on these plates and on those exposed to the violet rays; and this appearance is more striking on some contact positives than on the original negatives. But the appearances all but fail under the test of micrometer readings: the most that could be made of the strongest examples, with all bias in favour of the widening, was about $\frac{1}{100}$th of a millimetre, and from this we have to deduct something for the photographic widening, which, as pointed out by our President on a former occasion, is due to the feebler light of the spot, which is equivalent to a shorter exposure. An attempt was made to measure the amount of this deduction on some imitation spot bands obtained as described in our report in the last February number of the *Monthly Notices*. But the only conclusion we could formulate was that no certain difference of measurement could be made out, although the appearance of widening was more pronounced on the real spot bands than on their imitations.

The denser spots appear to stop out the photospheric radiation almost completely. On some plates exposed to one of the very dark spots crossing the solar disc in the first week of 1893 September, which bear the evidence of a steady image

during the exposures, the absorption lines can be seen crossing the spot band, but only with the aid of a slotted screen to stop out the rest of the picture; and on these we can find no appearance of widening.

2°. The double reversals of the calcium lines at H and K are greatly weakened over spots. This is so remarkable that it has appeared probable that over a full-grown spot there is no reversal of these lines, and that what is seen on some of the plates is only the effect of tremor of the image, on account of which a neighbouring bright facula often occupies its place on the slit and leaves its impression on the plate. On several plates which bear the marks of an unusually steady image, and which show a dense spot, the faculous reversals are nearly cut out by the spot band.

3°. In the immediate neighbourhood of a spot the bright reversals, if double at all, are usually only very feebly so, the central absorption being almost completely wanting, and the radiations thick and strong and closing up.

4°. At a distance from the spot the doubling of the reversal is more pronounced, and the bright components are thinner.

5°. There are traces on some plates of a continuous spectrum from the faculous matter, and occasionally this continuity is more marked through a range of a few tenth-metres on either side of H and K than elsewhere.

So far as these observations may be considered facts, they seem to be confirmations of the action in spot formation as given by the writer in a paper contributed to *Astronomy and Astro-Physics* of 1893 November. It was there noted that the precedence of small bright faculæ, in the order of time, was in favour of an uprush of heated gaseous matter, which, arriving at the higher elevations, radiated its light through a less depth of absorbing medium. The immediate result of this position of advantage for radiation would be the appearance of the bright lines of its constituents if they were not lost by projection upon the brilliant general spectrum of the solar light; but one of them escapes this obliteration owing to the dark background provided for it in the solar spectrum by the extensive absorption of calcium vapour,* and it is through the marks of this radiation on our photographic plates that we learn something of the history of these great luminous clouds. Their bright radiation shows where they are, but of itself leaves it uncertain whence they came. They must be above the reversing layer, and are certainly at a higher tem-

* Recently Monsieur Deslandres has shown the existence of other constituents in the bright faculous matter, by some beautiful photographs of their forms over the solar surface, taken with his double-slit spectroscope directed on an apparently dark iron line. The writer had the privilege of examining one of these plates on the occasion of its author's visit to Stonyhurst in the summer, and saw that the photographic map of the faculous matter obtained by iron radiation was substantially the same as the map given by the calcium light.

perature than their surroundings at their new elevation. They may have come up from below with the greater heat of a lower level, or they may have come from without and have been raised to a higher temperature by arrested motion. But they are at their highest elevation in the immediate vicinity of a spot, and lower at a distance from it; for close to a spot there is little or no double reversal, while away from it the central absorption is wide and strong—in other words, near a spot there is little or no superincumbent absorbing medium, while away from it there is much. For this reason it seems probable that the faculous clouds are thrown up from below, forming a rent in the solar atmosphere, where they leave a vast region of greatly reduced pressure and consequent chill, to account for the condensations which stop out the light from the photosphere and form the spot. They would attain their highest elevation directly over or near to the spot, and, drifting away, would gradually fall down. In the first days of its life the spot would be hidden from our sight by the bright faculæ directly over it; their nascent brightness would be enough to hide the spot in the telescope, and their partial continuous spectrum would mask its effect in the spectroscope. The spot would thus begin to appear as a dark speck in the midst of bright faculæ, and would grow to our vision as the faculous clouds uncover it falling down the slopes, like lava from a crater. This falling down is prettily shown on some of our plates by a V-shaped double reversal with the apex close to the spot band, and on others by a double V- or X-shaped reversal cut by the spot band through the centre. At the higher elevation the incandescent vapour is less dense and its radiation is narrower; falling, it becomes denser; its radiation is wider, but it is divided by greater central absorption.

Photographic Curves of Magnetic Variations, and their Connection with Solar Disturbances.—A comparison between terrestrial magnetism and solar surface disturbances, during the same period of least solar activity, shows a complete lack of agreement between them. With the charts of the solar surface, and the daily magnetic curves, to refer to, it was an easy task to pass in review the Earth's magnetic condition at every arrival of a group of spots and faculæ at the central meridian, or at the eastern or western limbs of the Sun. This was carefully done for three of the most disturbed regions, and the results were so contradictory of any supposable law that it was considered useless to continue the examination in this way. The converse method was then followed. A list of the greater magnetic disturbances furnished the dates for comparison with the sun-spot charts; and it was found that not only no condition, age, or position of spots or faculæ could be divined from the magnetic variations, but also that the greatest magnetic disturbance of the twelve months occurred at a time of complete and prolonged calm on both hemispheres of the solar surface. These magnetic perturbations

began about 6 P.M. on November 26, lasting through the night, and were repeated the two following nights, beginning a little later each night. Our own evidence of the solar calm at this time is nearly complete, and shows that no spot appeared on the surface of the Sun between the middle of October and the middle of December; and the absolutely complete daily record of the solar surface given in the Greenwich volume of 1889 from observations at the Royal Observatory, and those of India and the Mauritius, show the same complete calm. It must, therefore, be considered certain that, whatever connection there may be between some sun-spots and our magnetic disturbances, the one is not the cause of the other, and there are causes of the one which do not affect the other. At present we can go no further than admit that there may be some common cause of both phenomena, and that at one time the Earth is more within its reach than the Sun; at another, the Sun is nearer to its influence than the Earth. This common cause may be some form of cosmical stuff crossing our planetary system. There might be times in our history when we encounter it in greater quantities, and these times might occur periodically. We should then have greater and more frequent solar disturbances, and greater and more frequent magnetic storms, but not necessarily synchronously. This periodicity seems to be true, for we find more magnetic disturbances at periods of greater solar activity.

We are in need of other evidence of the existence of this cosmical stuff, and herein is our weakness. If it exists, we are too near it to see it. Many of the cloud forms which grace our skies would vanish into apparent nothingness on a near approach to them. We are probably too near the Zodiacal light to make much of our observations of its behaviour, and so this cosmical stuff would, if it actually exists, elude our notice.

Stonyhurst College Observatory:
1894 *November.*

Photographs of the Nebulæ ♅ *I.* 84, *h* 1442, *and* ♅ *II.* 344 *Comæ Berenicis.* By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebulæ ♅ I. 84, *h* 1442, and ♅ II. 344 *Comæ Berenicis*, R.A. $12^h\ 45^m$, Decl. north 26° 5′, was taken with the 20-inch reflector on 1894 May 7, with exposure of the plate during 90 minutes, and the two copies now presented are enlarged, one to 1 millimetre to 24 seconds of arc, and the other to the scale of 1 millimetre to 6 seconds of arc.

The nebula ♅ I. 84 is No. 4725 in the *New General Catalogue*, and 3249 in the *General Catalogue*, where it is described by Sir J. Herschel as very bright; very large; extended; very suddenly very much brighter in the middle, with a bright nucleus.

Lord Rosse (*Observations of Nebulæ and Clusters of Stars*, p. 121) records six observations of the nebula between 1850 and 1867, and describes it as another spiral with two arms and some stars in the *following* arm; the centre is bright; 12 minutes *preceding* and a little *south* is another nebula (*h* 1442) elongated; and 30 minutes *north following* is a third, elongated *north* and *south*.

The nebula (H I. 84) is by Lord Rosse described as very large and very bright. The centre itself is like an elongated nebula with nucleus. This centre is enveloped in an irregular ring or rings of nebulous light, and he gives a rough marginal sketch of it.

The nebula *h* 1442 is described as very patchy and a faint nucleus suspected, with one faint star south of it.

The photograph shows the nebula H I. 84 to be a symmetrical ellipse and not a spiral, with the major axis in *north following* to *south preceding* direction, and the nucleus is a nebulous star of about 12th magnitude. Both the star and the nebulosity surrounding it have well-defined margins, the nebulosity having a ringlike boundary. Surrounding the nucleus, at a great distance, is a well-defined ring, but deformed on the *north following* side, and in the ring are involved several starlike condensations of nebulosity. Outside this ring is another faint ring symmetrical with it, but discontinuous on the *north following* side, and there is in it some evidence of nebulous condensations; there is also some indication of the existence of another very faint ring outside this. In the divisions between the rings are five well-defined stars of 15th to 16th magnitude, that may or may not be physically connected with the nebula. Several of the features which I have referred to must have been observed by Lord Rosse.

The nebula *h* 1442 is 54 seconds of time *preceding* H I. 84, and has a stellar nucleus surrounded by nebulosity which is elongated nearly in *north* and *south* direction, and has two faint condensations involved. It is a small, faint, elliptical nebula.

The nebula H II. 344 is $1^m\ 18^s$ *following*, and 17 minutes of arc *north* of 84, and has a small bright stellar nucleus and dense nebulosity elongated in *north following* to *south preceding* direction. There are two faint starlike condensations of nebulosity *south preceding* the nucleus.

Photograph of the Nebulæ H I. 143 and II. 536 Virginis.

By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebulæ H I 143 and II 536 *Virginis*, R.A. $12^h\ 55^m$, Decl. 3° 4′ north, was taken with the 20-inch reflector on 1894 April 9, with exposure of the plate during three hours, and the copy now presented is enlarged to the scale of 1 millimetre to 6 seconds of arc.

The nebula H I 143 is No. 4900 in the *New General Catalogue*, and No. 3356 in the *General Catalogue*, and is described by Sir J. Herschel as considerably bright; considerably extended; star 10th mag., attached at about the position-angle 135°; four observations made. An engraving of the nebula is given in the *Philosophical Transactions* 1833, plate 14, fig. 67, but it does not well correlate with the photograph.

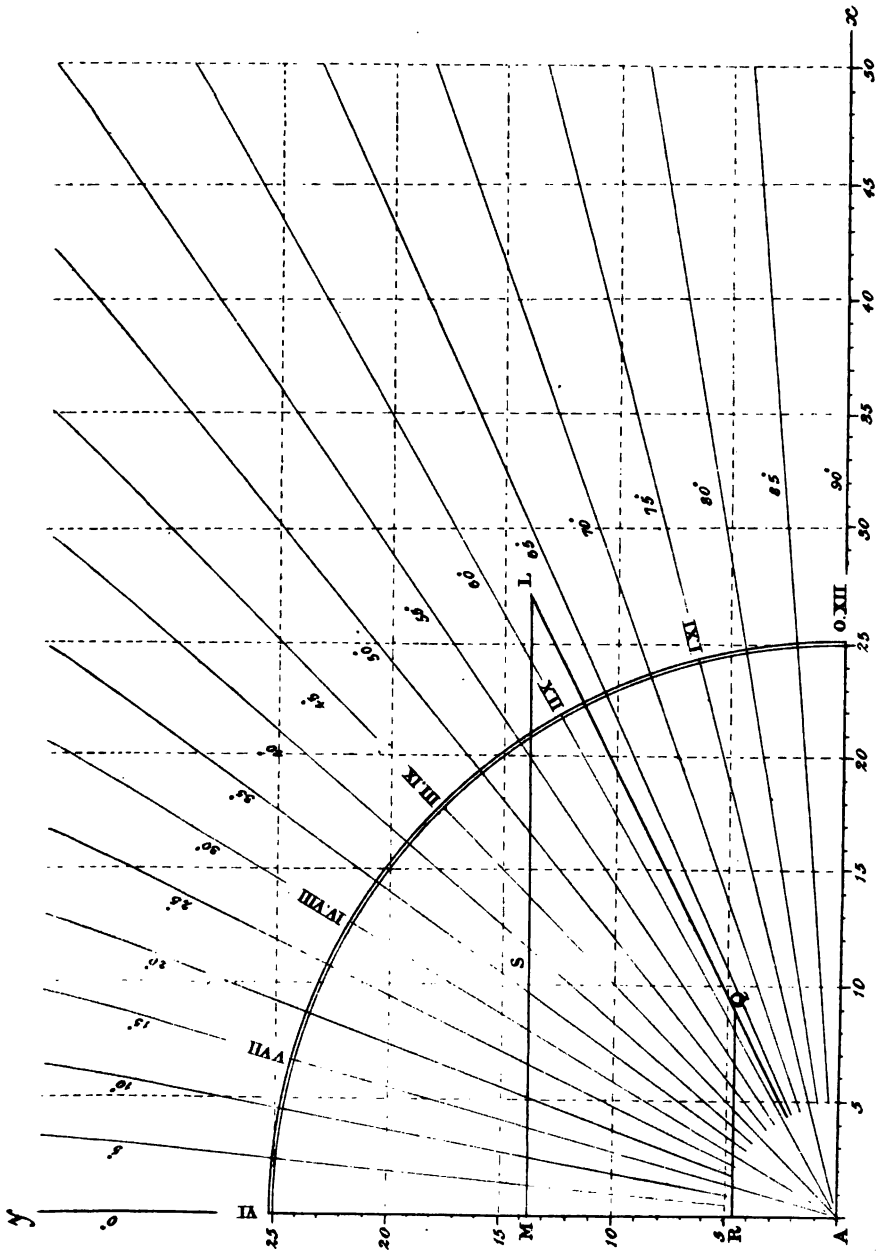
Lord Rosse (*Observations of Nebulæ and Clusters of Stars*, pp. 123, 124) records the results of seven observations made between 1855 and 1862, and he sometimes saw the nebula like the *Owl Nebula* (*h* 838), with a bright extended patch in the centre and dark spots on each side of this. Sometimes a dark ring is seen all the way round, but blackest to right and left (s.p. and n.f.). The nebulosity round is mottled, and he thought that sometimes he saw it as a spiral with a break in the outer annulus. "The darkness north of the nucleus (which is faint) certainly exists." A marginal sketch is given, but it does not resemble the photograph, except in the part which is circular in outline.

The photograph shows the nebula to somewhat resemble the letter D, with the curved side in *north preceding* direction, and a star of about 15th magnitude in the centre of curvature, the interior being filled with nebulosity of different densities, within which are five or six starlike condensations, and these give to the nebula the ring appearance referred to by Lord Rosse, but there is no spiral appearance visible in it as suggested by him. The less dense parts of the nebulosity are suggestive of dark lanes across the interior, but in reality they are the effect of contrast.

The *south following* part of the nebula is almost a straight line, with a star of about 13th magnitude close to it, but not in actual contact, and at sidereal time 10 hours on April 3 there was a minor planet* 317 seconds of arc *preceding*, and 317 seconds of arc *north* of the star above referred to. At sidereal time 10 hours on April 9 there was another minor planet at 57·83 minutes of arc *following*, and 383 seconds of arc *north* of the same star. The first of the minor planets would be equal to about 12th magnitude star, and the second to about 13th magnitude. I do not know if these planets have been previously discovered.

The nebula H II. 536 is also shown on the negative.

* Dr. Downing has kindly searched and found this planet to be *Hecate*


x
y
A
R
M
S
L
Q
0.XII
XI
X
IX
VIII
VII
VI
V
IV
III
II
I
0°
5°
10°
15°
20°
25°
30°
35°
40°
45°
50°
55°
60°
65°
70°
75°
80°
85°
90°

On the Computation of Star-corrections. By W. H. Finlay, M.A.

Professor Turner's paper in the April number of the *Monthly Notices* leads me to describe a diagram which I tried some years ago for computing star-corrections.

On squared paper a quadrant of a circle, with radius representing 25″, is drawn, and is graduated to every degree by radial lines from the centre A (plate 1). These graduations also represent angles of four minutes of time at A. (Only a few of these lines are shown in the figure, so as to avoid confusion.)

Ax is the initial line for time from 0^h to 6^h; Ay for time from 6^h to 12^h and for declination.

The star-corrections are given by the formulæ

$$\Delta\alpha = f + g \sin(G+\alpha) \tan\delta + h \sin(H+\alpha) \sec\delta$$
$$\Delta\delta = i \cos\delta + g \cos(G+\alpha) + h \cos(H+\alpha) \sin\delta.$$

The first step is to form the sums $(G+\alpha)$ for all the stars observed on any particular day, and with the corresponding value of g as radius describe a quadrant of a circle about A. Let S be the point where the radial line corresponding to a certain star's $(G+\alpha)$ cuts the circle of radius g.

Through S draw MSL, parallel to Ax, to meet the line of the star's declination in L. Then

$$LM = AM \tan\delta = g \sin(G+\alpha) \tan\delta$$

and

$$SM = g \cos(G+\alpha).$$

After these terms have been obtained for all the stars, the sums $(H+\alpha)$ are to be formed and a circle of radius h drawn. For convenience I shall use the same circle as before on the diagram, and take S as the point where the radial line to $(H+\alpha)$ cuts the circle of radius h.

Take AQ along the declination line of the star and equal to SM. Then

$$AL = AM \sec\delta = h \sin(H+\alpha) \sec\delta$$
$$QR = SM \sin\delta = h \cos(H+\alpha) \sin\delta.$$

The values of $i \cos\delta$ can be easily obtained by drawing a similar circle of radius i on the diagram, or (if i be very small) they can be taken from a little table. The corrections, therefore, are

$$\Delta\alpha = f + LM + AL$$

and

$$\Delta\delta = i \cos\delta + SM + QR.$$

When g is smaller than 3″ the first circle may be more conveniently described with a radius equal to $10g$, and the resulting values of LM and SM divided by 10. With a paper diagram it is not easy to avoid the formation of $G+\alpha$ and $H+\alpha$ for each star; but if the radial lines were ruled on some semitransparent surface and a graduated circle pivoted beneath it at A, then by turning this circle through an angle G, the values of the lines LM and SM could be read off at once with the argument α.

The chief merit of this diagram is that it gives the value of $\Delta\alpha$ directly instead of $\Delta\alpha \cos\delta$.

When the declination is very large the lengths ML and AL become unmanageable, but with a scale of $2\frac{1}{2}$″ to the inch there was no difficulty in working to 70° declination. Beyond this point the R.A. correction can be easily obtained from the diagram in the form $\Delta\alpha \cos\delta$, by proceeding in a manner somewhat similar to that described for the declination correction.

With this diagram star-corrections could be read in pretty rapidly; but, owing in great part to the imperfections of home-made scales, the results could not be depended on to within 0″·2. I therefore abandoned the diagram in favour of the tables described in *Monthly Notices*, vol. l. p. 497. These tables have been since completed, and have been in regular use at the Cape Observatory for the last two years. They are found to effect a saving of quite 33 per cent. in the time taken to compute star-corrections; they present no difficulty in working to quite inexperienced computers, and the results can be relied on to 0″·03.

The tables might have been compressed: the same value might have been chosen for g_0 and h_0, everything expressed in arc, and the R.A. correction obtained in the form $\Delta\alpha \cos\delta$; but after long consideration I decided on the present form. It is desirable to get the R.A. correction at once in time instead of in arc; even the simple operation of turning arc into time, if repeated four or five thousand times in a year, means delay; so P and Q are tabulated in seconds of time. Up to 60° declination the variations of P and Q are practically uniform through the degree, but beyond that point this is not quite true. The variations given after that are average variations, and consequently there may arise errors of one or two thousandths of a second in allowing for the minutes of the declination. The proportional part of the variation for one degree which corresponds to any given number of minutes is taken at sight from a table.

Beyond 70° declination I have modified the tables. Instead of $g_0 \sin\theta \tan\delta$ and $h_0 \sin\theta \sec\delta$, I have tabulated $g_0 \sin\theta \sin\delta$ and $h_0 \sin\theta$. The sum of P and Q has now to be multiplied by $\sec\zeta$. Their variations for a degree are very small, and their values, allowing for the minutes of declination, can be taken straight out.

The tables may also be used for the computation of the effects of precession, aberration, and nutation on micrometrical measures of distance and position-angle.

The formula for precession in distance may be put in the form

$$\frac{\Delta\sigma}{\sigma \sin 1''} = h \cos (H+\alpha) \cos \delta - i \sin \delta$$
$$= h \cos (H+\alpha) \sin (90°-\delta) - i \cos (90°-\delta)$$
$$= Q' (1+y) - I$$

where Q′ and I are to be taken from the table for declination $=90°-\delta$.

In position-angle we have

$$\Delta p = g \sin (G+\alpha) \sec \delta + h \sin (H+\alpha) \tan \delta$$
$$= g \sin (G+\alpha) \tan \delta \operatorname{cosec} \delta + h \sin (H+\alpha) \sec \delta \,.\, \sin \delta$$
$$= 15\, P (1+x) \operatorname{cosec} \delta + 15\, Q (1+y) \sin \delta.$$

Cape of Good Hope:
1894 *October* 10.

Note on the Binary Star κ Pegasi (β 989). By T. Lewis, Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

κ Pegasi	R.A.	$21^h\ 39^m\ 53^s{\cdot}4$	1895·0
	N.P.D.	$64°\ 58'\ 10''{\cdot}7$	

The small companion to *κ Pegasi* was noted in 1776 by Sir W. Herschel, and has been frequently measured as Σ 2824.

In 1880 August Mr. Burnham found the large star to be a close double (β 989). In the *Monthly Notices*, 1891 March, he gives all the measures and deduces a period of 11·13 years, thus making it the most rapid binary star known.

He remarks: "The extreme difficulty of measuring so close a pair seems to have deterred other observers, with a single exception, from doing anything with it. . . . It is unfortunate that we have so little to represent the extraordinary motion of this pair. . . . Since I have been at Mount Hamilton I have measured the close pair each year with the 36-inch refractor. During the measures of the past year it was extremely difficult, and was a severe test of the power of the great telescope with the very best atmospheric conditions."

This note naturally induced an inspection with the 28-inch refractor of the Royal Observatory, Greenwich, which showed them distinctly separated with a power of 1030, and our measures appear to confirm the remarkably short period.

The measures on the individual nights are :—

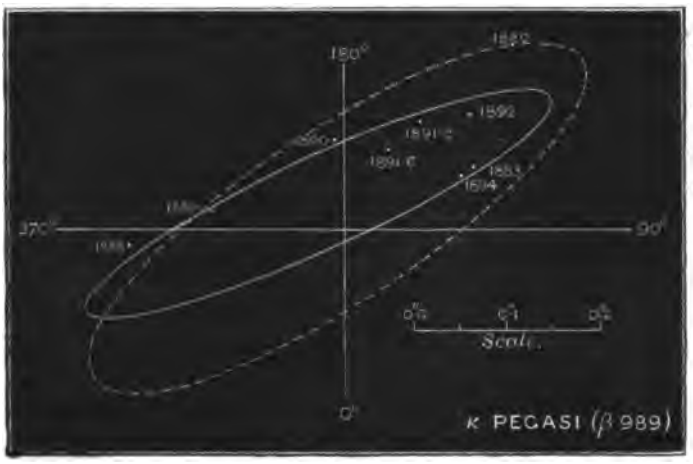
Date.	Position angle.	Distance.	Power.
1894, Oct. 27	108°5	0″·114	840
„ 29	122·1	0·157	840
Nov. 6	115·0	0·133	1030
„ 21	113·6	0·152	1030

the position-angles being in each case the mean of five settings. On Oct. 27 and 29 the distances were estimated in relation to the thickness of the micrometer wires, the values for which on careful determination were found to be 0″·114 and 0″·134. On the other nights direct measures were made.

The following are all the measures, and they are plotted down on the same scale as employed by Mr. Burnham in the paper quoted above :—

1880·68	137°9	0″·27	β	4*n*
1883·02	116·0	0·16	En.	1*n*
1887·78	274·7	0·23	β	3*n*
1889·51	262·3	0·14	β	4*n*
1890·57	187·1	0·10	β	4*n*
1891·61	150·0	0·10	β	3*n*
1891·81	144·6	0·13	β	4*n*
1892·39	132 8	0·18	β	4*n*
1894·83	114·8	0·14	L	4*n*

In the diagram shown below the dotted ellipse is that proposed by Mr. Burnham from his observations up to 1890, which would seem to want some modification to bring it more into accord with the recent measures. The narrower ellipse seems a nearer approximation to the apparent orbit.



The period is very nearly 11·6 years.

Mr. Burnham gives the magnitudes 4·3 and 5·0. As regards the distant Struve companion, the measures show rectilinear motion in the direction 72° of 0″·039 per annum; and if this is regarded as the proper motion of *κ Pegasi*, we have for this star a P.M. in

R.A. of + 0ˢ·0025

and in

N.P.D. of −0″·012

The measures are for Σ 2824—

1894·83 298°·8 and 12″·23.

The P.M. used for *κ Pegasi* is R.A. 000 and N.P.D. −0″·010 (Auwers). Bradley did not observe it in R.A.; but the Piazzi place gives P.M. in R.A. of + 0ˢ·0021.

Royal Observatory, Greenwich:
1894 *November* 2.

Since the above note was written I have found in *Popular Astronomy*, 1894 April, a discussion of this pair by Mr. Burnham, using his later measures, and another by Mr. Barnard, made with the 36-inch Lick refractor. His ellipse practically agrees with the one here given. The period he makes 11·37 years.

1894 *November* 8.

On the Orbit of η Cassiopeiæ (Σ 60).

By T. Lewis.

For various reasons this binary star is very interesting, and a better knowledge of its orbit seemed desirable. The following elements and notes are submitted in the hope that double-star observers will give it some attention.

The components are yellow and purple, and of the 4th and 7·6 mag. respectively.

The unusually large proper motion is in

R.A. +0ˢ·1346 and in N.P.D. +0″·481.

Its parallax has been determined by

Otto Struve	+0″·096	from measures of	distance
,, ,,	+0·373	,, ,,	position
Schweizer	+0·202	,, ,,	distance
,,	+0·139	,, ,,	position

A redetermination of parallax ought to be made.

The mean angular distance of the components is large (8″·4), and is only excelled by *Sirius* and *α Centauri*.

The orbits computed are

Computer.	Date.	P (years).	τ	e	Ω	γ	λ	a
					° ′	° ′	° ′	″
Powell	1861	181	1896·0	0·771	25 33	57 59	243 39	10·34
Dunér	1876	176·4	1924·8	·627	50 48	68 30	245 54	10·68
Doberck	1876	222·4	1909 2	·576	39 57	53 50	223 20	9·83
Grüber	1877	195·2	1901·3	·624	33 20	48 18	229 27	8·64
Coit	1882	167·4	1904·0	·622	41 2	52 5	233 6	8·70
Lewis	1894	208·1	1908·9	·500	47 6	47 36	214 10	8·45

It has, therefore, described over one-half its orbit while under observation, and there can be little doubt that the earlier computed dimensions of the orbit are too large.

Assuming the present elements, and adopting 0″·202 (the arithmetical mean) as the parallax, we find that the mean distance between the components is 41·84 times that between the Sun and the Earth, or 3,990,000,000 miles. *Neptune* is 30 times, or 2,700,000,000 miles.

Further, the combined mass is 3·54 that of the Sun, and the distance of the system from us is one million times the semi-diameter of the Earth's orbit.

Spectroscopic observations for motion in the line of sight would give further knowledge of this system.

I have compared the computed and mean observed places for each year, and although there are evidences of systematic error, there is a very fair agreement. As Mr. Coit published in *Monthly Notices*, 1882 May, a very complete set of observations, I think the following sufficient:—

Date.	Observed		Calculated	
	Angle.	Distance.	Angle.	Distance.
	°	″	°	″
1780·5	...	11·50	58·9	11·82
1782·5	60·1	...	60·2	11·87
1803·1	70·7	...	70·7	11·55
1819 8	80·2	10·20	79·9	10·63
1830·8	87·0	9·84	87·8	9·80
1840·4	96·2	8 95	95·8	8·93
1850·6	105 7	8 10	106 0	7·88
1860·6	116 8	7·02	119·4	6·90
1870·4	134·8	6·20	136 3	5·80
1880·3	160·2	5·30	159 6	5·31
1890·8	188·4	5·07	188·7	4·96
1894 1*	200·2	4·96	198·7	4·92

* I am indebted to Mr. Maw for this observation.

And an ephemeris for the next few years:—

1895·5	203°3	4″·85	1898·5	212°3	4″75
1896·5	206·3	4·82	1899·5	215 4	4 70
1897·5	209·3	4·79	1900 5	218·4	4 64

1894 *November* 5.

A Comparison between the Results of the Radcliffe Catalogue of Stars, 1890, *and the Greenwich Results*, 1887–91, *contained in the Greenwich Five-Year Catalogue*, 1890. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The Radcliffe Catalogue of 6,424 stars for the epoch 1890, which has just been distributed, and the Cape Catalogue for 1880, will afford positions of all the stars in the southern hemisphere of not less than the 7th magnitude, except those in clusters, and of fainter stars in those portions of the sky where there are no stars so bright as the 7th magnitude.

The Radcliffe Catalogue has been purposely made to overlap to a considerable extent the work of the Cape Catalogue in order to afford materials for a comparison of the results. A complete comparison of the positions of all the stars contained in these catalogues is nearly completed; the results show that the agreement both in right ascension and north polar distance between the Radcliffe Catalogue and the Cape Catalogue, 1880, is a very close one.

The comparison has also been extended to the stars common to the Radcliffe Catalogue and the Greenwich Catalogue for 1880.

These comparisons show that the north polar distance results of the Cape Catalogue fall between those of the two northern observatories, and that the differences are not large for either observatory. But the differences between the Radcliffe and Greenwich results are systematic, and are common to both the Greenwich Catalogue for 1880 and to the small catalogue of 258 fundamental stars, 1890 which has just been issued. I have given, therefore, in the present paper a table which shows the differences between the Radcliffe results and the Greenwich results for 1890 for the small catalogue of fundamental stars.

I need hardly say that all the corrections which I know to be necessary to clear the Radcliffe observations from systematic errors have been applied; but, of course, I do not expect that systematic errors have been entirely avoided. The differences between the direct and reflexion results found at Oxford have been too small, as may be seen on reference to the annual volumes for 1880-87, to render any corrections in this direction necessary; and the Radcliffe results are independent of *any*

empirical corrections. It is desirable to point out, what is certainly the fact, that the systematic corrections which have been applied to the Greenwich north polar distances for the "R—D discordance" are of the same order of magnitude and of sign as the discordances which exist between the Greenwich and Radcliffe results; and that the validity of the application of a correction of the form—constant × sine Z.D.—to the north polar distance observations when the constant used sensibly differs, as is the case at Greenwich, from that which is directly obtained for the horizontal flexure of the telescope, is, at least, very doubtful.

The corrections applied for R—D at Greenwich for some years past do not differ very greatly, and this proves that some such corrections are required to reconcile the *direct* and *reflexion* observations; but it certainly does not prove that such residual results can be correctly represented under the assumed form, and that they are applicable to the direct results, when the assumption appears to be negatived by the flexure observations.

The following table, extracted from the Greenwich volumes 1887–1891, gives the corrections applied to the direct north polar distance observations for those years, and these may therefore be taken as indicating the kind of corrections which have been applied to the results of the Greenwich 1890 Catalogue.

Correction for Discordance of Reflexion and Direct Results, Greenwich Observations.

N.P.D.	Corrections to Results of Direct Observations. 1887.	1891.
°	″	″
− 45	−0·69	−0·55
40	0·68	0·54
30	0·65	0·51
20	0·60	0·47
− 10	0·53	0·41
0	0·44	0·35
+ 10	0·34	0·27
20	0·23	0·18
30	−0·12	−0·09
40	0·00	0·00
50	+0·12	+0·09
60	0·24	0·18
70	0·34	0·27
80	0·44	0·34
90	0·52	0·41
100	0·59	0·46
110	0·63	0·50
120	0·66	0·52
+125	+0·67	+0·52
Horizontal Flexure.	−0″·06 sin Z.D.	+0″·06 sin Z.D.

The astronomical flexure of the telescope would, therefore, appear to be practically insensible, and quite inadequate to give rise to corrections such as those contained in the above table. It will be seen that in measuring directly a distance between the pole and the equator we have differences amounting to 0″·9, according as we apply or neglect these corrections.

I do not, of course, wish to assert that the discordances which exist between the Radcliffe and Greenwich observations are entirely due to the application of these corrections, or that the corrections applied at Greenwich are without warrant; but the discordances between the catalogues would certainly be much smaller if these corrections had not been applied, and the validity of the application of such corrections to the direct Greenwich results is, in my opinion, at least very doubtful.

The solar observations at Greenwich indicate that the Greenwich right ascensions should be increased; and this correction is in the direction indicated by the comparison between the Radcliffe and Greenwich observations so far as the stars in the northern hemisphere are concerned, but not for those in the southern hemisphere.

The comparison between the Radcliffe Catalogue, 1890, and the Cape Catalogue, 1880, show similar but much smaller changes of the differences in right ascension near the equator; and the mean differences between the Radcliffe and Cape Catalogues given by the general discussion are rather smaller than those indicated in the limited comparison here instituted through the stars common to the three catalogues.

Comparison between the Corresponding Results of the Radcliffe Catalogue of Stars for 1890 *with the Greenwich Five-Year Catalogue of* 258 *Fundamental Stars for* 1890.

	Limits of Group N.P.D.	Mean N.P.D. of Group.	Radcliffe minus Greenwich in R.A. × sin N.P.D.	Weight.	Radcliffe minus Greenwich in N.P.D.	Weight.	R−D applied to Greenwich Results.
	° °	°	s		″		″
1	−5–0	− 2	+0·001	422	−0·16	272	−0·38
	0–5	+ 2			+0·28	268	
2	6–22	15	−0·032	14	+0·23	36	−0·25
3	23–38¼	30	+0·009	19	−0·68	38	−0·11
4	38¼–58	50	+0·024	80	−0·78	80	+0·11
5	59–68	64	+0·040	257	−0·73	189	+0·25
6	69–78	73	+0·043	421	−0·83	279	+0·34
7	79–88	83	+0·035	550	−0·98	274	+0·42
8	89–98	93	+0·020	328	−0·87	177	+0·49
9	99–108	103	−0·020	295	−0·86	173	+0·54
10	109–120	114	−0·046	115	−1·16	76	+0·57

Procyon and *Sirius* have not been included in the comparison owing to their orbital motions, but the results would not have been sensibly affected if they had been included.

Comparison between the Results of the Radcliffe Catalogue, 1890, and the Cape Catalogue, 1880, for the same Stars for Groups 4, 5, 6, 7, 8, 9, and 10.

	Limits of Group N.P.D.	Mean N.P.D. of Group.	Radcliffe minus Cape Catalogue, 1880, in R.A.	Weight.	Radcliffe minus Cape Catalogue, 1880, in N.P.D.	Weight.
	° °	°	s		″	
4	38½–58	50	+0·031	30	−0·35	20
5	59–68	64	+0·052	199	−0·45	49
6	69–78	73	+0·046	358	−0·46	68
7	79–88	83	+0·037	509	−0·46	104
8	89–98	93	+0·028	414	−0·70	84
9	99–108	103	−0·007	323	−0·45	77
10	109–120	114	−0·005	250	−0·27	53

The weights of these comparisons and the accuracy of the mean differences are somewhat diminished from the comparatively few observations of the north polar distance of the northern stars contained in the Cape Catalogue, and the few southern stars contained in the Greenwich Catalogue, 1890.

The general discussion of the solar observations made at the Radcliffe Observatory gives with the latitude adopted in the General Catalogue a correction for the north polar distances of only −0″·015.

The comparisons here given show that the systematic differences between the Cape results and those of the two northern observatories are rather less than half a second of arc, and these differences include the errors of the refraction tables, with the effects due to different exposure of the thermometers, and any uncorrected division errors. The systematic differences between the different catalogues are certainly larger than could be wished, but a second of arc is only one ten-thousandth part of an inch on the Radcliffe circle.

Such comparisons as those here made appear to me to throw some light on the supposed inaccuracy of meridian observations.

When a sufficient number of observations are grouped together to reduce the errors of the refraction tables to mean errors, the results of the comparisons between the north polar distances contained in the Cape Catalogue of 1880 and the Greenwich and Radcliffe Catalogues lead to the following results :—

The observations contained in the Cape Catalogue, 1880, gave directly zenith distances, and they were referred to the south polar point, with a zenith distance of the polar point determined from observation, subject also to errors of determination instrumental and reductional, including the errors of the refraction

tables with the *adopted* thermometer exposures. The southern observations thus gave independent south polar distances.

The corresponding observations included in the Radcliffe Catalogue, 1890, have given independent north polar distances subject to similar errors of zenith distance and of polar point.

These results are only comparable on the assumption that the angle between the polar points is *exactly* 180°. We are, therefore, when the observations are thus independently referred to the north and south polar points, measuring 180° when comparing north polar distances made at the northern and southern stations; and when, therefore, the mean differences between the northern and southern observations are confined within such limits as $\pm 0''.5$ we are practically obtaining results within the $\frac{5}{180\times60\times60\times10}$ part, or the $\frac{1}{1296000}$ part of the quantity measured. It remains to be proved that other astronomical methods are more accurate than meridian observations for the measurement of such large angles.

It is undoubtedly true that small angles can be measured with much greater accuracy by other methods; but when differential methods are adopted we have to guard against an accumulation of the effects of the errors made in passing by summation from the small angles directly measured to the larger angles with which we are concerned in practice.

Radcliffe Observatory, Oxford:
1894 *November* 8.

Comparison of the Pulkowa Catalogue, 1885, *with the Greenwich Ten-Year*, 1880, *and Five-Year*, 1890, *Catalogues.* By W. G. Thackeray, Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations of the Pulkowa Catalogue for 1885 extend over the years 1882–1891, and are a continuation of the series of declinations made with the vertical circle at Pulkowa, of which the Catalogues for 1845 and 1865 are well known. Before the observations for the present catalogue were begun the vertical circle was thoroughly overhauled, the pivots re-turned, and the circle re-divided. The Catalogues for 1865 and 1885 are in all respects similar, and the observations are reduced with the same refraction and the same value of co-latitude. The results for 1885 have been further corrected for variation of latitude in accordance with a paper of M. Nyrén's in *Bulletin de l'Acad. de St-Pétersbourg*, N.S. III.

From a comparison with the results of the 1865 Catalogue, M. Nyrén concludes that the adopted refractions would be better for

a correction to the logarithm of the constant of refraction of $-0\cdot00121$, that is $\rho = 57''\cdot358$, and an increase in the coefficient of the thermometer $dm = +0\cdot0001021$, or $m = 0\cdot0047121$ for 1° R, the general effect of the combined correction being to diminish the adopted refractions.

The Greenwich Catalogue, 1880, extends over the years 1877–1886, and the 1890 Catalogue from 1887 to 1891. The adopted value of the latitude, 51° 28′ 38″·1, is the same for both catalogues. The observations have been reduced with Bessel's refractions, and corrected for R—D by the formula $a+b\sin z$.

Auwers's proper motions have been used both at Greenwich and Pulkowa.

The stars common to the three catalogues are 167 in number, and the comparison has been effected by bringing up the Pulkowa places for 1885 to 1890 by using Auwers's P.M.'s, from his re-reduction of Bradley's observations, and the mean of the precessions as given in the Pulkowa and Greenwich, 1890, Catalogue. The differences exhibited are the apparent corrections to reduce the Greenwich Catalogues to Pulkowa.

For convenience we will call the Pulkowa Catalogue "P," and the Greenwich Ten-Year, 1880, G_X and the Five-Year, 1890, G_Y. Then

TABLE I.

Star's Name.	Approx. R.A.	N.P.D. Pulkowa 1885 reduced to 1890.	No. of Obs.	Sees. of N.P.D. 1890·0 deduced from 1887–1891 Greenwich Five-Year Cat.	No. of Obs.	Sees. of N.P.D. Greenwich Ten-Year Cat., 1880, reduced to 1890.	No. of Obs.	P−G_Y	P−G_X
	h m	° ′ ″		″		″		″	″
α Andromedæ	0 3	61 31 1·08	23	0·61	34	0·86	42	+0·47	+0·22
γ Pegasi	0 8	75 25 41·34	16	40·96	19	41·35	32	+0·38	−0·01
ι Ceti	0 14	99 26 2·14	12	1·82	14	2·20	20	+0·32	−0·06
ε Andromedæ	0 33	61 17 8·50	9	7·84	15	8·54	25	+0·66	−0·04
α Cassiopeiæ	0 34	34 3 57·84	44	58·68	6	58·30	31	−0·84	−0·46
β Ceti	0 38	108 35 25·85	29	26·38	14	26·17	25	−0·53	−0·32
μ Andromedæ	0 51	52 5 50·84	8	50·61	9	50·78	28	+0·23	+0·06
ε Piscium	0 57	82 42 8·11	8	8·97	10	8·54	47	−0·86	−0·43
β Andromedæ	1 4	54 57 46·31	8	46·19	22	45·89	52	+0·12	+0·42
Polaris	1 18	1 16 41·73	719	41·54	626	41·63	1433	+0·19	+0·10
θ Ceti	1 19	98 45 4·34	10	4·74	4	4·41	11	−0·40	−0·07
η Piscium	1 26	75 13 17·71	9	17·38	14	17·52	34	+0·33	+0·19
ο Piscium	1 40	81 23 46·44	10	46·11	25	46·52	28	+0·33	−0·08
ζ Ceti	1 46	100 52 43·95	10	43·69	7	43·97	8	+0·26	−0·02
ε Cassiopeiæ	1 46	26 52 19·53	26	19·06	7	19·81	40	+0·47	−0·28

Star's Name.	Approx. R.A.	N.P.D. Pulkowa 1885 reduced to 1890.	No. of Obs.	Secs. of N.P.D. 1890·0 deduced from 1887–1892 Greenwich Five-Year Cat.	No. of Obs.	Secs. of N.P.D. Greenwich Ten-Year Cat., 1880, reduced to 1890.	No. of Obs.	P−G$_V$	P−G$_X$
	h m	° ′ ″		″		″		″	″
β Arietis	1 49	69 43 48·10	10	47·80	26	48·11	66	+0·30	−0·01
γ Andromedæ	1 57	48 11 54·68	12	54·07	4	54·16	32	+0·61	+0·52
α Arietis	2 1	67 3 29·32	35	29·03	25	29·30	72	+0·29	+0·02
ξ^2 Ceti	2 22	82 2 0·39	10	0·33	19	0·17	25	+0·06	+0·22
δ Ceti	2 34	90 8 47·24	9	46·52	13	47·32	19	+0·72	−0·08
γ Ceti	2 38	87 13 41·54	8	41·35	13	41·84	14	+0·19	−0·30
α Ceti	2 57	86 20 32·36	18	32·28	10	32·15	21	+0·08	+0·21
δ Arietis	3 5	70 41 23·64	9	23·58	19	23·19	24	+0·06	+0·45
α Persei	3 16	40 30 51·50	36	51·41	3	51·92	20	+0·09	−0·42
ε Tauri	3 19	81 21 31·41	10	31·88	11	31·75	22	−0·47	−0·34
f Tauri	3 25	77 26 27·26	8	27·02	21	27·16	21	+0·24	+0·10
ε Eridani	3 28	98 49 51·98	10	51·35	7	52·33	20	+0·63	−0·35
δ Eridani	3 38	100 8 10·58	10	10·81	8	11·10	15	−0·23	−0·52
η Tauri	3 41	66 14 8·12	10	8·23	14	8·46	33	−0·11	−0·34
γ Eridani	3 53	103 49 19·33	11	18·92	14	19·51	13	+0·41	−0·18
γ Tauri	4 14	74 38 19·39	9	18·96	12	19·04	23	+0·43	+0·35
ε Tauri	4 22	71 3 51·41	8	50·71	12	51·76	13	+0·70	−0·35
α Tauri	4 30	73 42 45·07	17	45·00	35	45·07	53	+0·07	0·00
μ Eridani	4 40	93 27 24·87	10	24·82	10	25·13	11	+0·05	−0·26
ι Aurigæ	4 50	57 0 31·87	10	31·35	7	31·51	16	+0·52	+0·36
ε Leporis	5 1	112 31 10·29	11	10·04	4	10·28	25	+0·25	+0·01
α Aurigæ	5 9	44 6 52·93	39	53·89	5	53·28	18	−0·96	−0·35
β Orionis	5 9	98 19 45·81	19	44·98	11	45·68	36	+0·83	+0·13
β Tauri	5 19	61 29 10·68	17	9·93	19	10·51	46	+0·75	+0·17
δ Orionis	5 26	90 22 52·89	10	52·42	11	52·40	24	+0·47	+0·49
α Leporis	5 28	107 54 5·72	11	6·08	3	6·47	25	−0·36	−0·75
ε Orionis	5 31	91 16 22·40	10	22·19	7	21·74	17	+0·21	+0·66
κ Orionis	5 43	99 42 33·77	10	33·48	7	33·92	16	+0·29	−0·15
α Orionis	5 49	82 36 51·15	17	50·79	26	51·13	43	+0·36	+0·02
β Aurigæ	5 51	45 3 52·42	18	51·44	1	52·66	9	+0·98	−0·24
η Geminorum	6 8	67 27 43·70	10	43·69	4	43·86	17	+0·01	−0·16
μ Geminorum	6 16	67 25 50·73	10	50·43	16	50·61	24	+0·30	+0·12
β Canis Majoris	6 18	107 54 6·62	12	7·32	6	7·02	11	−0·70	−0·40
γ Geminorum	6 31	73 30 27·45	9	26·98	25	27·37	54	+0·47	+0·08
ξ Geminorum	6 39	76 59 11·42	9	11·43	22	11·74	21	−0·01	−0·32

Star's Name.	Approx. R.A.	N.P.D. Pulkowa 1885 reduced to 1890.	No. of Obs.	Recs. of N.P.D. 1890·0 deduced from 1887–1891 Greenwich Five-Year Cat.	No. of Obs.	Recs. of N.P.D. Greenwich Two-Year Cat., 1880, reduced to 1890.	No. of Obs.	P−G$_Y$	P−G$_X$
	h m	° ′ ″		″		″			
α Canis Majoris	6 40	106 33 56·63	35	59·22	7	58·42	43	(−2·59)	(−1·79)
Cephei 51	6 49	2 46 54·66	53	54·72	265	54·96	595	−0·06	−0·30
ζ Geminorum	6 58	69 16 8·68	10	8·48	14	8·62	39	+0·20	+0·06
δ Geminorum	7 14	67 48 57·10	10	57·21	10	57·01	45	−0·11	+0·09
β Canis Minoris	7 21	81 29 22·86	10	23·01	14	22·90	25	−0·15	−0·04
α^2 Geminorum	7 28	57 52 15·45	20	15·36	24	15·33	67	+0·09	+0·12
α Canis Minoris	7 34	84 29 37·47	18	36·22	22	36·35	71	(+1·25)	(+1·12)
β Geminorum	7 39	61 42 31·87	18	31·91	18	31·56	78	−0·04	+0·31
ρ Argus	8 3	113 59 15·77	11	16·06	7	15·72	15	−0·29	+0·05
β Cancri	8 11	80 28 33·67	10	33·93	15	33·84	18	−0·26	−0·17
ε Hydræ	8 41	83 10 41·14	10	41·16	2	41·16	16	−0·02	−0·02
ι Ursæ Majoris	8 52	41 31 37·29	19	37·66	4	37·07	6	−0·37	+0·22
α Cancri	8 52	77 43 0·64	9	1·36	10	1·09	28	−0·72	−0·45
α Hydræ	9 22	98 10 54·91	17	55·73	11	56·01	30	−0·82	−1·10
o Leonis	9 35	79 36 27·43	11	27·50	14	27·63	28	−0·07	−0·20
ε Leonis	9 40	65 43 10·76	11	10·67	8	10·71	27	+0·09	+0·05
μ Leonis	9 47	63 28 31·40	10	31·13	29	31·25	39	+0·27	+0·15
α Leonis	10 3	77 29 43·69	17	43·56	29	44·09	81	+0·13	−0·40
γ^1 Leonis	10 14	69 36 8·58	9	8·61	15	8·80	50	−0·03	−0·22
μ Hydræ	10 21	106 16 30·08	12	30·62	8	30·29	21	−0·54	−0·21
ρ Leonis	10 27	80 7 39·64	10	39·45	9	39·41	29	+0·19	+0·23
α Ursæ Majoris	10 57	27 39 19·18	46	19·67	10	19·40	101	−0·49	−0·22
δ Leonis	11 8	68 52 25·59	14	25·38	21	25·44	64	+0·21	+0·15
δ Crateris	11 14	104 10 59·54	11	60·14	9	60·44	21	−0·60	−0·90
λ Draconis	11 25	20 3 42·72	22	43·12	17	42·95	60	−0·40	−0·23
υ Leonis	11 31	90 12 59·66	11	59·40	12	59·52	47	+0·26	+0·14
β Leonis	11 43	74 48 47·39	18	47·29	24	47·40	52	+0·10	−0·01
β Virginis	11 45	87 36 55·66	16	55·69	10	55·63	32	−0·03	+0·03
γ Ursæ Majoris	11 48	35 41 37·08	33	37·28	7	37·10	35	−0·20	−0·02
o Virginis	12 0	80 39 22·15	10	22·41	18	21·97	22	−0·26	+0·18
ε Corvi	12 4	112 0 29·14	10	29·49	6	29·08	20	−0·35	+0·06
η Virginis	12 14	90 3 19·62	11	19·63	10	19·54	33	−0·01	+0·08
δ Corvi	12 24	105 54 10·64	12	11·14	19	11·01	27	−0·50	−0·37
β Corvi	12 29	112 47 18·65	10	18·20	8	18·81	15	+0·45	−0·16
γ^2 Virginis	12 36	90 50 48·33	10	48·91	4	48·52	14	−0·58	−0·19

Star's Name.	Approx. R.A.	N.P.D. Pulkowa 1885 reduced to 1890.	No. of Obs.	Secs. of N.P.D. 1890·0 deduced from 1887–1891 Greenwich Five-Year Cat.	No. of Obs.	Secs. of N.P.D. Greenwich Ten-Year Cat., 1880, reduced to 1890.	No. of Obs.	P−G$_V$	P−G$_K$
	h m	° ′ ″		″		″		″	″
δ Virginis	12 50	86 0 17·06	9	16·83	21	17·01	19	+0·23	+0·05
α Canum Ven.	12 51	51 5 15·07	11	14·91	6	15·04	40	+0·16	+0·03
ε Virginis	12 57	78 26 58·41	10	58·24	9	58·50	52	+0·17	−0·09
α Virginis	13 19	100 35 13·12	105	13·42	19	13·42	86	−0·30	−0·30
ζ Virginis	13 29	90 1 60·07	8	59·87	30	59·63	36	+0·20	+0·44
τ Bootis	13 42	71 59 41·62	8	41·49	17	41·47	21	+0·13	+0·15
η Ursæ Majoris	13 43	40 8 15·11	59	15·61	2	15·30	42	−0·50	−0·19
η Bootis	13 49	71 3 2·69	10	2·71	33	2·28	59	−0·02	+0·41
τ Virginis	13 56	87 55 22·57	8	22·29	18	22·39	33	+0·28	+0·18
α Draconis	14 1	25 5 53·93	20	53·85	23	53·82	77	+0·08	+0·11
κ Virginis	14 7	99 45 41·31	10	41·32	26	41·14	34	−0·01	+0·17
α Bootis	14 11	70 14 40·89	114	40·83	62	40·80	184	+0·06	+0·09
ρ Bootis	14 27	59 8 44·13	10	43·82	9	43·67	27	+0·31	+0·46
ε Bootis	14 40	62 27 42·61	8	42·30	19	42·40	71	+0·31	+0·21
α^2 Libræ	14 45	105 35 3·02	17	3·88	15	3·79	47	−0·86	−0·77
β Ursæ Minoris	14 51	15 23 41·91	32	41·68	21	41·66	98	+0·23	+0·25
β Bootis	14 58	49 10 31·22	8	31·81	4	30·50	9	−0·59	+0·72
β Libræ	15 11	98 58 35·74	10	36·29	6	36·10	22	−0·55	−0·36
α Coronæ	15 30	62 54 53·64	16	53·05	38	53·79	71	+0·59	−0·15
α Serpentis	15 39	83 13 40·70	16	40·63	35	40·54	29	+0·07	+0·16
ε Serpentis	15 45	85 11 27·36	9	26·79	22	26·71	25	+0·57	+0·65
ζ Ursæ Minoris	15 48	11 52 3·07	16	2·50	19	2·60	28	+0·57	+0·47
γ Serpentis	15 51	73 58 44·56	9	44·24	15	44·79	14	+0·32	−0·23
β Scorpii	15 59	109 30 13·25	9	13·64	16	13 88	26	−0·39	−0·63
δ Ophiuchi	16 9	93 24 38·38	10	38·49	24	38·26	37	−0·11	+0·12
γ Herculis	16 17	70 35 17·93	9	17·58	12	17·37	41	+0·35	+0·56
η Draconis	16 23	28 14 12 76	26	12 09	5	12·31	45	+0·67	+0·45
Antares	16 23	116 11 13·83	8	15·09	9	14·14	32	−1·26	−0·31
λ Ophiuchi	16 25	87 46 29·42	10	29·18	10	29 63	21	+0·24	−0·21
ζ Ophiuchi	16 31	100 21 37·60	10	37·55	23	37 66	23	+0·05	−0·06
ζ Herculis	16 37	58 11 51·81	9	52·10	16	51·36	56	−0·29	+0·45
κ Ophiuchi	16 52	80 27 13·05	9	12 98	24	13·23	44	+0·07	−0·18
ε Herculis	16 56	58 54 40·98	9	40·44	11	40·58	38	+0·54	+0·40
ε Ursæ Minoris	16 57	7 46 57·68	17	57·42	25	57·99	21	+0·26	−0·31
η Ophiuchi	17 4	105 35 17·06	9	17·34	35	17·40	24	−0·28	−0·34
α Herculis	17 10	75 29 2·31	16	1·86	29	2·10	38	+0·45	+0·21

Star's Name.	Approx. R.A.	N.P.D. Pulkowa 1885 reduced to 1890	No. of Obs.	Secs. of N.P.D. 1890·0 deduced from 1887–1891 Greenwich Five-year Cat.	No. of Obs.	Secs. of N.P.D. Greenwich Ten-Year Cat., 1880, reduced to 1890.	No. of Obs.	P−G_V	P−G_X
	h m	° ′ ″		″		″		″	″
β Draconis	17 28	37 37 1·38	19	1·39	9	1·17	25	−0·01	+0·21
α Ophiuchi	17 29	77 21 34·22	16	34·10	65	34·40	79	+0·12	−0·18
β Ophiuchi	17 38	85 23 10·86	10	10·37	42	10·89	45	+0·49	−0·03
μ Herculis	17 42	62 12 52·97	8	52·58	21	52·63	49	+0·39	+0·34
γ Draconis	17 54	38 29 52·97	36	52·68	13	52·49	46	+0·29	+0·48
72 Ophiuchi	18 2	80 27 5·23	10	5·00	27	5·30	37	+0·23	−0·07
μ Sagittarii	18 7	111 5 12·42	11	13·59	11	13·53	19	−1·17	−1·11
δ Ursæ Minoris	18 8	3 23 18·27	55	18·05	232	18·46	589	+0·22	−0·19
η Serpentis	18 16	92 55 37·18	11	36·98	30	36·77	38	+0·20	+0·41
α Lyræ	18 33	51 19 6·44	17	6·44	76	6·40	217	0·00	+0·04
β Lyræ	18 46	56 45 53·10	8	53·13	11	52·71	33	−0·03	+0·39
ε Aquilæ	18 55	75 4 50·71	8	51·02	24	50·49	58	−0·31	+0·22
ζ Aquilæ	19 0	76 17 58·96	10	58·76	48	59·10	73	+0·20	−0·14
δ Aquilæ	19 20	87 6 15·15	9	14·87	34	14·64	36	+0·28	+0·51
λ Ursæ Minoris	19 34	1 1 59·61	27	59·19	227	59·37	489	+0·42	+0·24
γ Aquilæ	19 41	79 39 16·14	16	16·31	10	16·42	24	−0·17	−0·28
α Aquilæ	19 45	81 25 18·47	17	19·12	30	19·04	59	−0·65	−0·57
β Aquilæ	19 50	83 52 3·60	16	3·32	13	3·08	28	+0·28	+0·52
θ Aquilæ	20 6	91 8 50·46	10	50·35	33	50·20	52	+0·11	+0·26
α^2 Capricorni	20 12	102 53 7·19	16	8·04	13	7·41	19	−0·85	−0·22
β Capricorni	20 15	105 7 41·88	10	41·43	9	42·45	33	+0·45	−0·57
ρ Capricorni	20 23	108 10 36·91	10	37·11	6	36·79	23	−0·20	+0·12
ε Delphini	20 28	79 4 13·15	8	13·43	23	13·66	23	−0·28	−0·51
α Delphini	20 35	74 28 32·81	9	32·55	5	33·04	25	+0·26	−0·23
α Cygni	20 38	45 6 45·19	39	45·03	3	45·65	27	+0·16	−0·46
ε Aquarii	20 42	99 53 52·99	11	53·49	13	53·30	26	−0·50	−0·31
61 Cygni	21 2	51 47 28·94	10	29·18	4	29·23	15	−0·24	−0·29
ζ Cygni	21 8	60 13 26·93	8	26·58	27	26·84	51	+0·35	+0·09
α Equulei	21 10	85 12 24·31	8	23·80	9	24·15	18	+0·51	+0·16
α Cephei	21 16	27 52 49·36	49	49·25	24	49·92	77	+0·11	−0·56
β Aquarii	21 26	96 3 17·66	10	17·74	15	17·51	36	−0·08	+0·15
β Cephei	21 27	19 55 19·52	36	19·49	12	20·10	74	+0·03	−0·58
ε Pegasi	21 39	80 37 44·93	9	45·18	21	45·21	37	−0·25	−0·28
δ Capricorni	21 41	106 37 34·15	12	34·82	9	34·26	10	−0·67	−0·11
α Aquarii	22 0	90 51 14·51	18	14·45	24	14·29	34	+0·06	+0·22

Star's Name.	Approx. R.A.	N.P.D. Pulkowa 1885 reduced to 1890.	No. of Obs.	Secs. of N.P.D. 1890·0 deduced from 1887–1891 Greenwich Five-Year Cat.	No. of Obs.	Secs. of N.P.D. Greenwich Ten-Year Cat., 1880, reduced to 1890.	No. of Obs.	P−G$_V$	P−G$_X$
	h m	° ′ ″		″		″		″	″
ι Pegasi	22 2	65 11 31·32	8	30·56	13	31·76	33	+0·76	−0·44
γ Aquarii	22 16	91 56 29·51	10	29·10	16	29·25	13	+0·41	+0·26
η Aquarii	22 30	90 41 3·88	10	3·57	20	3·56	15	+0·31	+0·32
ζ Pegasi	22 36	79 44 34·29	9	34·12	25	34·52	15	+0·17	−0·23
μ Pegasi	22 45	65 58 45·06	8	44·61	13	45·30	41	+0·45	−0·24
λ Aquarii	22 47	98 9 53·50	10	53·96	14	53·62	42	−0·46	−0·12
α Pegasi	22 59	75 23 11·85	16	11·47	14	11·83	30	+0·38	+0·02
γ Piscium	23 11	87 19 7·89	9	7·73	14	7·62	44	+0·16	+0·27
ι Piscium	23 34	84 58 12·19	8	12·04	14	11·90	27	+0·15	+0·29
γ Cephei	23 35	12 58 53·54	19	52·80	24	53·69	68	+0·74	−0·15
ω Piscium	23 54	83 44 44·98	9	44·42	24	44·83	38	+0·56	+0·15

In those cases where there are fewer than 10 observations in the Greenwich Five-Year Catalogue, the mean N.P.D. 1890·0 deduced from the observations 1887–1891, has been used instead of the adopted Catalogue place, which was found by a combination of the observations in 1887–1891 with the Ten-Year Catalogue.

The weights adopted for combining the results are from the formula

$$\frac{4\,mn}{m+n+\frac{1}{6}\,mn},$$

where m and n are the number of observations of any star in any two of the catalogues. The results given by *Sirius* and *Procyon* have not been used. The general apparent mean correction to the Greenwich Ten-Year Catalogue is − 0″·04, and to the Five-Year Catalogue + 0″·06, or to the mean of the two, practically zero.

The following are the differences arranged in order of time for every six hours of right ascension, and corrected for the general mean.

	0^h − 6^h	6^h − 12^h	12^h − 18^h	18^h − 24^h
	″	″	″	″
P−G$_X$	+0·01	−0·07	+0·09	−0·04
P−G$_V$	+0·13	−0·17	+0·01	−0·03
P−½ (G$_X$+G$_V$)	+0·07	−0·12	+0·05	−0·04

Arranging them again for every 10° of N.P.D., the mean N.P.D. and difference become

N P.D.	3°	15°	26°	36½°	44°	55½°	65°	75°	84°	94½°	104½°	113°
P−G$_V$	+″·20$_3$	+″·40$_4$	+″·05$_6$	−″·15$_4$	−″·19$_8$	+″·12$_{11}$	+″·30$_{21}$	+″·14$_{28}$	+″·09$_{29}$	+″·07$_{25}$	−″·33$_{18}$	−″·44$_8$
P−G$_X$	−·09	−·02	−·17	+·04	−·07	+·22	+·03	−·03	+·03	+·03	−·37	−·24
P−½(G$_X$+G$_V$)	+·06	+·19	−·06	−·05	−·13	+·17	+·16	+·06	+·06	+·05	−·35	−·34

The subscribed numbers denote the numbers of stars on which the results depend, and which are the same in every case.

The places of stars whose N.P.D.'s lies between 0° and 41° depend on below pole as well as above pole observations.

The results are more accordant than might have been expected from the small number of stars on which some of the quantities depend, and indicate that the system of reductions and the constants in use at the two observatories give practically identical results. The tendency to run off at the end is not in favour of M. Nyrén's proposed diminution of the adopted Pulkowa refractions.

Indirectly we get the following comparison between the Greenwich Ten-Year, 1880, and Five-Year, 1890, Catalogues.

G$_V$−G$_X$	+″·29	+″·42	+″·22	−″·19	−″·12	−″·10	+″·27	+″·17	+″·06	+″·04	+″·04	−″·22

For a comparison between the refractions of Bessel's tables and those of Pulkowa, reference should be made to Professor Simon Newcomb's paper on the Greenwich North Polar Distances, in vol. ii. pp. 418–424 of the Astronomical Papers prepared for the use of *The American Ephemeris and Nautical Almanac.*

Royal Observatory, Greenwich:
1894 *November* 6.

Diagram showing the apparent discordances in North Polar Distances between the Mean of the Greenwich Ten-Year (1880) and Five-Year (1890) Catalogues, and the Pulkowa Catalogue 1885, reduced to 1890.

Note on the Latitude of the Royal Observatory, Cape of Good Hope. By David Gill, LL.D., F.R.S., Her Majesty's Astronomer at the Cape.

In the introduction to the Cape Catalogue for 1885, recently printed, there is given a discussion of the systematic errors of the Declinations of the Greenwich Ten-Year Catalogue and the Cape General Catalogue for 1885.

The results of that discussion show that if the co-latitudes are

$$\text{For Greenwich } 38^\circ\ 31'\ 21''\cdot90 + X,$$
$$\text{„ Cape } \quad 123\ 56\ 3\cdot35 + x;$$

then

$$X = -0''\cdot103; \qquad x = +0''\cdot186.$$

Further, the refractions of the *Tabulæ Regiomontanæ* require to be multiplied by the following factors :—

At Greenwich by $(1-0\cdot00217)$
„ the Cape by $(1-0\cdot00218)$
} The zenith distances being limited to 80°.

The general accuracy of these interdependent results has been remarkably confirmed as follows :—

As an independent control on the system of declinations, a number of pairs of stars was selected for observation with the zenith telescope, and some years ago a list of these pairs of stars was forwarded to Dr. Otto Struve (then Director of the Pulkowa Observatory), with a request that the northern stars of the list should be observed at Pulkowa, either by referring them to the Pulkowa fundamental stars with the transit circle, or observing them fundamentally with the vertical circle.

Dr. Struve expressed the opinion that for such work he considered the vertical circle should be employed; that Dr. Nyrén was unable to undertake observations of the complete list with the vertical circle, but had promised to observe a list of twenty-two stars of special importance, and he hoped that Dr. Romberg would be able to observe the others with the transit circle.*

These twenty-two northern stars were selected in such a way that for each of eleven southern circumpolars there should be one northern star forming a Talcott-latitude pair with it at upper culmination, and another at lower culmination. The twenty-two

* I am since informed that Dr. Romberg has observed these stars with the transit circle, but the results have not yet reached me.

Talcott pairs thus formed were observed with the zenith telescope at the Cape, and the twenty-two northern stars were observed by Dr. Nyrén with the vertical circle at Pulkowa. The results of Dr. Nyrén's observations were kindly communicated by him on 1889 March 9, and are also published in the *Astronomische Nachrichten*, No. 2904.

In the mean of two latitude pairs, in one of which the south component is a circumpolar star at upper transit, and in the other pair the southern star is the same circumpolar at lower transit, it is clear that the mean declination of the south stars (apart from change of latitude between the epochs of observation of the two pairs) must be rigorously = 90°. The deduced latitude from pairs thus combined will therefore rest entirely on the Pulkowa declinations, and be independent of errors in the assumed places of the southern circumpolars.

The results are based on four observations of each northern star at Pulkowa, and on ten to twelve observations of each pair with the zenith telescope at the Cape.

The Cape observations extend from 1886 to 1891, and the effect of change of latitude is practically eliminated, as is shown by the results with and without Chandler's corrections for change of latitude.

With the places of the northern stars given in the *Ast. Nach.*, No. 2904, the reduction of the observations gives (Introduction to Cape Catalogue for 1885·0, pp. xlvi, xlvii)

Latitude of the Cape transit circle...	$-33^\circ\ 56'\ 3''.65$
The latitude derived from the discussion of the Cape and Greenwich transit-circle observations being	3·54
Difference	0·11

But within the past few days the Pulkowa Observations, Series II. vol. i., has reached the Cape. In the list of stars occasionally observed Dr. Nyrén there gives the finally discussed positions of the twenty-two northern stars. Employing these corrected positions in lieu of those published in the *Ast. Nach.*, No. 2904, the latitude of the Cape comes out

	$-33^\circ\ 56'\ 3''.57$
Or, as above, from the meridian observations	3·54
Difference	0·03

This remarkable agreement between results arrived at by methods, instruments, and observers so entirely distinct from each other cannot but be regarded as extremely satisfactory. The separate results are given below :—

South Star.	North Star.	Excess of North Z.D. 1887·0.	Resulting Latitude. Without Chandler's Corrections.	With Chandler's Corrections.
		"	° ′ ″	″
Brisb. 4091 S. P.	Pulk. (1855) 115	+229·04	−33 56 3·50	3·49
Brisb. 4091	Pulk. (1855) 1829	−501·03		
Stone 7461 S. P.	W_2 1h 758–60	+345·30	3·27	3·25
Stone 7461	Pulk. (1855) 1927	+517·07		
Lac. 1848	Pulk. (1855) 475	− 50·76	3·49	3·50
Lac. 1848 S. P.	Pulk. (1855) 2202	−383·19		
Stone 9273 S. P.	Arm.$_2$ 573	+503·25	3·55	3·53
Stone 9273	Pulk. (1855) 2483	−254·21		
Lac. 1839	Pulk. (1855) 732	−307·52	3·93	3·93
Lac. 1839 S. P.	Pulk. (1855) 2417	− 9·06		
Stone 2901	Pulk. (1855) 1052	+264·89	3·64	3·62
Stone 2901 S. P.	Pulk. (1855) 2603	+ 67·07		
σ Octantis S. P.	Pulk. (1855) 1148	−201·22	3·73	3·74
σ Octantis	Pulk. (1855) 2706	+423·58		
A Octantis	Pulk. (1855) 1196	−492·94	3·40	3·38
A Octantis S. P.	Lalande 37406–7	− 48·63		
τ Octantis S. P.	Arm.$_2$ 1259	− 91·51	3·51	3·50
τ Octantis	Arm.$_2$ 3116	+279·08		
Lac. 4578	W_2 10h·1118	−313·33	3·65	3·62
Lac. 4578 S. P.	Arm.$_2$ 3084	−127·62		
Stone 6404	Pulk. (1855) 1719	+118·21	3·75	3·72
Stone 6404 S. P.	Pulk. (1855) 3403	− 80·61		
	Means...		−33 56 3·58	3·57
	Probable Error		±0·04	±0·04

Royal Observatory, Cape of Good Hope:
1894 *October* 16.

Preliminary Note on the Position of the Liverpool Observatory.

By W. E. Plummer, M.A.

In the Annual Report of the Council for the year 1867 it is stated : "From five transits of *β Draconis*, four of *γ Draconis*, and one of *α Cygni*, each of them over the east and west prime verticals, the latitude (of the Liverpool Observatory) is 53° 24′ 3″·8 N." As far as I know, no details have ever been published, nor can I find in the archives of the Observatory any record of the observations.

It was with the view of confirming this result, and also to test how far the instrument was available for the accurate determination of latitude, that the following observations were undertaken.

The Observatory is not equipped with a transit circle, but a third pier has been erected to the north of the eastern pier at right angles to the meridian, and at such a distance as to permit the transit instrument being placed between this and the eastern pier. The Y bearings and the mounting generally are in all respects similar to those employed when the instrument is on the meridian. The new position of the line of collimation is 1 foot 8 inches north of the ordinary transit.

The means for reversal of the instrument are not convenient, and the operation cannot be effected under about three minutes, so that it is only for stars which cross within a few minutes of the zenith that it is possible to reverse the telescope during the transit. Practically the instrument has only been reversed for the determination of collimation, and the whole of the transit has usually been made in either the north or the south position. Neither could the telescope be used as a zenith instrument in the ordinary Talcott or Horrebow method. For these reasons it has been necessary to rely on pairs of observations of the same stars made on different nights in reversed positions of the axis.

It was originally intended to bisect the star when near the prime vertical by the micrometer wire, noting the time ; but this method had to be abandoned, not only because the micrometer was in a very inconvenient position for reading when the telescope was nearly vertical, but the earlier observations so made showed that there was some loss or irregularity in the screw which it was impossible to make entirely disappear. These observations have accordingly all been rejected, and those observations only have been retained which depend upon transits over the fixed wires of the instrument.

These are nine in number, and under the most favourable circumstances could only give four contacts in each reversed position of the instrument—another reason for not reversing during each transit. The intervals between these wires, when de-

termined by means of the movable thread being brought into coincidence with each, exhibited the same uncertainty as that already noticed, and furnished additional grounds for the rejection of the earlier observations.

The wire intervals used depend entirely upon the meridional transits of polar stars, and are, I believe, perfectly trustworthy. The derivation of the intervals from the prime vertical observations themselves shows a satisfactory accord with those used.

The level corrections have always been small and consistent, and the practice has been to determine the level error at least three times in the course of the observations, practically about once an hour. There has been noticed an occasional tendency for the northern pier to sink (or the southern pier to rise) as the night wore on. The maximum effect has been to alter the level about 1″ in the course of the evening. The probable error of a single determination, however, is as much as 0″·2. It does not seem possible to connect this gradual change with temperature, since it is not always present, nor when the greatest range of temperature has been noticed. The value of the level scale 0″·90 is that which has been in use for some years. I have no adequate means of making a fresh determination. Practically, if ΔL be the correction to the level scale, the final latitude would have to be increased by 1·35 ΔL. An examination of the level errors as applied to separate values of the latitude in north and south positions of the instrument has not, however, shown the necessity of any correction.

The azimuth has remained small and constant throughout the observations. Sometimes stars at a considerable distance from the zenith have been observed, but it has been found sufficient to determine the hour angle of the meridian of the instrument from the zenith stars themselves. The correction $\frac{1}{2} a^2 \sin 1'' \cot \phi$ has never been sensible.

The transits have been made by the chronographic method. For slow-moving stars the method is probably inferior to eye and ear transits, but owing to the relative situation of the piers and the clock, the latter could not be seen when observing, and one was liable to errors in counting. The clock error and rates were so completely under control, that any error caused by their variation is of a smaller order than the error of observation.

Since there was no object in observing very close to the zenith, either with the view of reversing the telescope during the transit or from fear of irregularity in the performance of the clock, the choice of the selected stars depended upon the accuracy with which the transits could be made, and the effect of this error upon the latitude. If ϵ be the probable error in the time of transit, and t half the interval of time between E. and W. vertical circles, then the effect on the latitude ϕ is

$$d\phi = \frac{\epsilon}{2} \sin 2\phi \tan t.$$

It was found that the probable error of observation was sensibly the same for all transits in which t exceeded 20°, and that, practically, the increase in the error of observation when t was less than 7° increased the error of the latitude. The minimum effect on the latitude was produced when t was about one hour or when $(\phi - \delta)$ was about one degree. As the effect of an error in the assumed declination of the star on the resulting latitude is expressed by

$$d\phi = d\delta \frac{\sin 2\phi}{\sin 2\delta},$$

possibly a slight increase in the accuracy might have resulted by making $\phi - \delta$ a larger angle; but this slight gain is more than compensated by the longer interval in the transit and the greater danger of losing the second by clouds.

On these considerations the following list of stars, arranged in order of $(\phi - \delta)$, was drawn up from the most authentic sources attainable. The declinations have been reduced as far as possible to the A. G. C. system, and the proper motions have in general been taken from the discussion of proper motion, vol. xxv. of the *Annals of the Harvard Observatory*. In a few cases the proper motion has been independently determined. The programme provided for observing each star five times in both north and south positions, and this rule has been very generally adhered to. The stars *c*, *f*, *l*, and *m* have, however, only been observed four times, the west transit being lost from clouds. An increase in the number of observations did not sensibly increase the accuracy of the result derived from each individual star, and of course the error in the assumed declination remained practically unremoved. It seemed more advantageous to increase the number of the stars than to multiply observations of the same star.

Letter of Reference.	Star's Name.	Assumed Declination. 1894·0.	Assumed Proper Motion.	Approximate Right Ascension. 1894·0.	Authority.
		° ′ ″	″	h m s	
a	51 Draconis	53 14 2·25	+0·027	19 2 33·2	Gr. 80, Pulk. 55, Harv. 75.
b	κ Cygni	53 10 22·31	+ ·112	19 14 39·2	Berliner Jahrbuch 1894.
c	Groomb. 3403	53 7 49 74	+ ·006	21 6 58·9	Gr. 72, Pulk. 55, Gl. 70, Harv. 75.
d	Groomb. 2671	52 52 16·02	− ·034	18 44 25·2	Gr. 80, Rad. 45, Gr. 60, Harv. 75.
e	Groomb. 3383	52 51 49·21	·000	21 0 33·3	Gr. 80, Rad. 45, Wash. 60, Harv. 75.
f	Groomb. 3042	52 51 8·37	+ ·253	20 3 26·5	Gr. 72, Pulk. 55, Rad. 45, Harv. 75.
g	Groomb. 2699	52 50 20 14	+ ·352	18 49 12·7	Gr. 64, Pulk. 55, Wash. 60, Harv. 75.
h	Groomb. 3100	52 47 52·83	+ ·163	20 10 51·8	Rad. 45, Brus. 65, Harv. 75.
i	Groomb. 3090	52 47 21·76	− ·013	22 3 30·1	Wash. 60, Rad. 45, Harv. 75.
j	Groomb. 3617	52 44 24·58	·000	21 51 47·6	Gl. 70, Brus. 65, Rad. 45, Harv. 75.
k	20 Cygni	52 43 8·01	− ·132	19 47 58·1	Gr. 80, Pulk. 55, Rad. 45, Harv. 75.
l	Groomb. 3285	52 36 34·67	− ·100	20 43 16·9	Gl. 70, Brus. 65, Rad. 45, Harv. 75.
m	Groomb. 3434	52 36 33·75	− ·033	21 16 16·2	Rad. 45, Harv. 75.
n	Groomb. 3436	52 31 39·41	+ ·052	21 16 33 9	Rad. 45, Harv. 75 (double).
o	Groomb. 3480	52 29 29·33	+ ·031	21 26 48·6	Gr. 80, Pulk. 55, Rad. 45, Harv. 75.
p	Groomb. 3467	52 26 16·83	·000	21 23 15·3	Gr. 80, Rad 60, 45, Brus. 65, Harv. 75
q	ψ Cygni	52 9 26 75	− ·046	19 52 53 4	Berliner Jahrbuch, 1894.
r	Groomb. 2753	52 6 27·15	− ·010	18 59 37·5	Rad. 45, Harv. 75.
s	ι Cygni	52 6 15·87	− ·060	19 24 50·3	Gr. 72, Gr. 60, Rad. 45, Harv. 75.
t	Groomb. 3213	51 56 54·70	+ ·063	20 28 19·5	Rad. 45, Bonn 55, Harv. 75.
u	Lalande 40328	51 31 1·79	·000	20 45 30·8	Gr. 80, Brus. 65, Harv. 75.
v	Groomb. 3239	51 29 19·09	+ ·014	20 31 45·2	Gl. 70, Brus. 65, Rad. 45, Harv. 75.

As an example of the agreement in the individual results determined from each of the two positions of the telescope, as well as to exhibit the constancy of the errors of the instrument, the latitude derived from the separate nights' observations of one star, the first in the list, is given. The collimation error has been determined both by reversion and by reflection. The level errors where a gradual change has been noticed as the night advanced have been varied with the time, the quantity shown in column 5 being that actually used; the azimuthal error has never been sufficiently large to be applied. In the final values for the latitude there remains only the correction due to the employment of inaccurate values in the intervals of the wires, and this is effectually masked by the errors of the observations themselves.

Date.		Position of Lamp.	$\phi' - \delta_a$	Error of Collimation Lamp N.	Inclination.	Azimuthal Error.	Appt. δ.	Latitude.
1894.			′ ″	″	″	″	° ′ ″	° ′ ″
Sept.	5	N.	9 48·24	+1·74	+2·62	−3·12	53 14 13·96	53 24 4·82
	6	S.	9 48·08	+2·03	+2·05	−3·05	14·12	4·25
	10	S.	9 48·97	+2·30	+0·41	−1·92	14·75	4·13
	13	N.	9 49·18	+1·60	+0·73	−1·47	15·15	5·06
	14	S.	9 48·68	+ ·42	+1·25	−0·73	15·28	5·20
	24	N.	9 45·32	+ ·27	+3·02	−1·25	16·31	4·65
	27	N.	9 43·94	− ·35	+3·87	−0·96	16·51	4·32
	29	S.	9 48·40	+ ·11	+0·26	−2·42	16·63	5·29
Oct.	1	S.	9 46·95	− ·86	+1·62	−3·80	16·73	5·30
	2	N.	9 47·77	−1·03	+0·83	−1·35	16·76	5·26

The mean results from each of the stars are as follows :—

Star.	Mean Latitude.	Average Deviation.	Star.	Mean Latitude.	Average Deviation.
	° ′ ″	″		° ′ ″	″
a	53 24 4·83	0·40	*l*	53 24 5·63	0·39
b	5·25	0·53	*m*	5·22	0·56
c	5·04	0·36	*n*	4·39	0·75
d	4·27	0·62	*o*	4·70	0·32
e	4·64	0·44	*p*	4·28	0·41
f	4·32	0·53	*q*	5·44	0·38
g	4·98	0·39	*r*	5·04	0·83
h	5·45	0·70	*s*	4·31	0·36
i	5·21	0·63	*t*	5·29	0·42
j	3·97	0·75	*u*	4·70	0·55
k	4·26	0·58	*v*	5·04	0·70

The average deviation of each determination from the mean is given, from which the probable errors could easily be derived; but the uncertainty in the assumed declination of the star remains, though it is hoped that to some extent its influence on the final result is removed by employing a considerable number of stars. In presence of this uncertainty, however, it does not seem desirable to adopt any more elaborate method of deducing the mean result than to take the arithmetic mean, and this gives for the latitude of the Liverpool Observatory 1894·7 53° 24′ 4″·84.

An examination of the residuals discloses the unwelcome fact that they are rather large, and that the further prosecution of the subject with the present instrument is not likely to be of any scientific value as a contribution to the question of the variation of the latitude.

Longitude.

The information concerning the longitude determination is as vague as that of the latitude. In the Report of the Council, 1868, already quoted, it is stated that the difference of longitude between the old and the new observatory was "found by the transmission of sixty chronometers to be $17^{s}\cdot04$." The longitude of the old observatory was determined by the late Astronomer Royal in the course of the Valentia inquiry (1844), and is quoted for several years in the *Nautical Almanac* as $12^{m}\,0^{s}\cdot11$ W.

So far as can be gathered from the records, these sixty chronometers were simply carried from one observatory to the other in the ordinary course of removal, no repetition of the journey being made. Consequently any error in the original determination of clock error impressed itself on the result. Circumstances pointed to the fact that these errors might be considerable, both in the last clock error in the old observatory, and in the first in the new. Further, the longitude of the old observatory rested entirely on the results of the chronometrical expedition in 1844, and might very well be repeated by the method of galvanic signals. It is true that the 1862 determination of the Feagh Main Station by this process agreed very closely with the older result, so that no considerable alteration in the assumed longitude of the new observatory could be anticipated, but the connecting link between the two seemed sufficiently weak to make a fresh inquiry desirable.

The method employed was the exchange of signals recorded on the respective chronographs of the two observatories, the clock errors being determined at each observatory in the ordinary course of observation. The hour chosen for the exchange of signals was 9 P.M., a time when, weather permitting, observations were usually going on, and any uncertainty in the clock rate was practically avoided. The clock employed here was the Bond clock, mentioned in the Report of the Council, 1868. It has

always given me most trustworthy results. The Astronomer Royal has kindly furnished me with the clock errors and rates of the sidereal standard employed at Greenwich.

With regard to the Liverpool observations, it may be mentioned that the collimation error has been determined both by observations of the reflected wire and by transits of polar stars in reversed positions of the intrument. The agreement between the two methods is not very satisfactory, though the difference is by no means systematic. The want of stability in the screw mentioned in the case of the latitude observations is the probable cause of the disagreement, and, as a matter of fact, the collimation error rests entirely on the observation of polar stars. The variation of the error from night to night is very small, and it is believed that the error itself is accurately known. The level error has been found by means of a striding level, and the remarks on the determination of its scale referred to in the earlier sections are to be considered here. The results of the prime vertical observations have, on the whole, convinced me of the very approximate accuracy of the scale value. The level error has also been derived from reflection; but here, again, the method has never recommended itself. The azimuthal error has been derived from the observation of the ordinary polar stars, including those whose places are given in the *Connaissance des Temps.* Within the period embraced by the longitude observations, seven stars were used.

Owing to some difficulty in making the proper connections with the Liverpool chronograph, the Greenwich signals failed to register for the first few nights, and not all the signals (thirty from each station) sent from Liverpool were registered at Greenwich. The "relay time" (shown below), however, seems sufficiently well known from the latter part of the inquiry to warrant the application of one-half the mean interval to the earlier observations.

	Relay Time. Mean of 20 Signals.	Relay Time. Mean of 10 Signals.
	s	s
Aug. 30	(−0·003) (only 8 recorded)	
Sept. 4	+ ·016	+0·024
5	+ ·020	+0·035
6	+ ·006	+0·038
12	+ ·025	+0·032
13	+ ·017	+0·049
19	+ ·027	+0·022
20	+ ·015	+0·010
26	+ ·024	+0·039
Mean	+ ·019	+0·031

The mean $0^s{\cdot}023$ has been assumed as the correct interval on those days on which the signals were not efficiently exchanged.

Two attempts were made to determine the personal equation of the Liverpool observer, referred to the Greenwich standard. The results are not very satisfactory. Bad weather defeated the earlier attempt, the only result being to show that the personal equation was practically zero. At the second attempt the following, not very accordant results, were obtained :—

Date.	Greenwich—Liverpool (Clock Slow).	Date.	Greenwich—Liverpool (Clock Slow).
	s		s
1894 April 21	+0·33	1894 April 28	0·00
26	−0·10	May 1	+0·14
27	+0·17		

The mean $+0^{s}\cdot11$ has been employed in the derivation of the following values of the longitude from each of the nights on which signals were satisfactorily exchanged :—

		m s			m s
1893 Aug. 9	Long. W.	12 17·34	1893 Sept. 6	Long. W.	12 17·27
15		17·24	12		17·33
16		17·24	13		17·42
23		17·36	19		17·39
30		17·30	20		17·34
Sept. 4		17·38	26		17·33
5		17·37			

The mean of these values it is proposed to adopt for the present, and the resulting position of the Liverpool Observatory is—Latitude, N. 53° 24′ 4″·8 ; Longitude, W. 12^{m} $17^{s}\cdot33$.

Liverpool Observatory,
1894 *November* 8.

Observations of Comet II. 1894 (*Gale*). By W. E. Plummer, M.A.

The following observations of Gale's Comet have been made with the equatorial of the Liverpool Observatory. When the comet was sufficiently bright to admit of any illumination in the field the observations were made with a filar micrometer. The remainder, marked "Ret.," have been made by a micrometer of thick wires crossed at right angles, and placed at an angle of 45° with the meridian. Five transits have usually been made when this micrometer has been used. All the observations have been corrected for differences of refraction, but no corrections for parallax have been applied. In the column "Observer," the letters "P." and "S." refer to Mr. Plummer and Mr. Skinner, respectively :—

Liverpool Mean Time of Observation.				☄−✱ R.A.	No. of Comparisons (α).	Apparent R.A. of ☄.	☄−✱ Declination.	No. of Comparisons (δ).	Apparent Declination of ☄.	Log Factor of Parallax in (α).	Log Factor of Parallax in (δ).	Observer.	Star of Reference.
1894.	h	m	s	m s		h m s	′ ″		° ′ ″				
May 4	8	37	2	+8 58·51	13	8 28 17·01	+10 9·7	3	− 3 14 19·6	9·3966	0·8617	P.	*a*
...				+7 53·97	13	8 28 16·30	+19 25·1	3	− 3 14 16·4	...	...	P.	*b*
7	9	34	11	+ 22·60	16	8 27 59·99	+15 58·5	4	+ 7 29 58 3	9·4629	0·8204	P.	*c*
9	10	2	58	+1 0·02	16	9 15 2·56	+ 1 5·5	4	+13 23 19·5	9·4952	0·7966	P.	*d*
...				− 29·66	16	9 15 2·64	−10 33·0	4	+13 23 17·4	...	...	P.	*e*
10	9	53	37	− 49·33	13	9 22 44·36	+ 5 17·4	3	+15 55 24·2	9·4846	0·7781	P.	*f*
	10	7	49	− 44·84	12	9 22 48·85	+ 6 44·9	3	+15 56 51·7	9·5013	0·7883	S.	*f*
12	11	13	46	+ 39·21	16	9 37 19·20	+ 1 14·7	4	+20 28 18·3	9·5600	0·7883	P.	*g*
	11	20	47	− 6·26	12	9 37 21·32	−11 47·1	3	+20 28 55 0	9 5634	0·7922	P.	*h*
16	10	35	22	+1 44·19	16	10 1 14·16	+ 4 57 0	4	+27 5 20·7	9·5480	0·7168	P.	*i*
...				− 37·88	16	10 1 14·52	− 5 52·9	4	+27 5 21·3	...	...	P.	*j*

1894.	Liverpool Mean Time of Observation. h m s	♂−✱ R.A. m s	No. of Comparisons (α).	Apparent R.A. of ♂. h m s	♂−✱ Declination. ′ ″	No. of Comparisons (δ).	Apparent Declination of ♂. ° ′ ″	Log Factor of Parallax in (α).	Log Factor of Parallax in (δ).	Observer.	Star of Reference.
May 17	9 38 40	+ 43·51	12	10 6 18·62	− 58·4	3	+28 21 5·5	9·5181	0·5594	P.	*k*
	9 45 52	+ 45·05	12	10 6 20·16	− 35·8	3	+28 21 28·1	9·4898	0·6651	S.	*k*
18	10 26 5	−3 10·80	20	10 11 29·72	+ 6 40·4	5	+29 35 15·7	9·5464	0·6860	P.	*l*
	10 35 55	−3 8·87	20	10 11 31·65	+ 7 11·2	5	+29 35 46·5	9·5566	0·6929	S.	*l*
21	9 45 59	+1 43·28	Ret.	10 25 6·73	+ 1 6·6	Ret.	+32 34 6·4	9·5039	0·6148	P.	*m*
	...	−1 24·22	,,	10 25 6·59	+ 3 52·6	,,	+32 34 5·9	9·5039	0·6148	P.	*n*
21	9 59 3	+1 45·64	,,	10 25 9·09	+ 1 33·8	,,	+32 34 33·6	9·5238	0·6278	P.	*m*
	...	−1 21·69	,,	10 25 9·12	+ 4 20·0	,,	+32 34 33·3	...	...	S.	*n*
24	10 12 30	− 22·58	20	10 37 11·82	− 9 31·9	5	+34 54 30·7	9·6533	0·6151	P.	*o*
	...	+1 7·00	20	10 37 11·94	− 9 37·1	5	+34 54 32·1	...	...	P.	*p*
27	12 2 5	− 49·25	16	10 48 9·36	+ 2 47·4	4	+36 46 2·4	9·6410	0·7270	P.	*q*
28	10 12 35	+2 22·93	16	10 51 12·86	− 5 0·3	4	+37 14 33·0	9·5685	0·6956	P.	*r*
	10 28 42	+2 24·96	16	10 51 14·89	− 4 39·1	4	+37 14 54·2	9·5871	0·6128	S.	*r*
29	11 6 34	−1 44·04	20	10 54 32·52	+11 5·7	5	+37 44 18·9	9·6226	0·6542	P.	*s*
	...	+3 28·12	20	10 54 32·66	− 14·0	5	+37 44 19·7	...	...	P.	*t*
30	10 55 28	+3 57·05	16	10 57 37·02	− 2 41·6	4	+38 10 32·5	9·5534	0·5546	P.	*u*
	...	−3 25·77	16	10 57 36·85	−10 2·2	4	+38 10 30·7	...	...	P.	*v*
31	10 36 20	−1 56·53	20	11 0 35·47	+ 1 10·6	5	+38 34 59·9	9·6053	0·6073	P.	*w*
	11 19 5	−1 51·22	20	11 0 40·78	+ 1 52·6	5	+38 35 41·9	9·6371	0·6646	S.	*w*

1894.	Liverpool Mean Time of Observation.	☄−✱ R.A.	No. of Comparisons (α).	Apparent R.A. of ☄.	☄−✱ Declination.	No. of Comparisons (δ).	Apparent Declination of ☄.	Log Factor of Parallax in (α).	Log Factor of Parallax in (δ).	Observer.	Star of Reference.
	h m s	m s		h m s	′ ″		° ′ ″				
June 6	10 15 40	+1 14·72	Ret.	11 16 59·60	+ 5 20·6	Ret.	+40 30 16·4	9·6508	0·6520	P.	*x*
20	10 22 7	+ 26·29	,,	...	+ 3 0·2	,,	...	9·6471	0·5819	P.	...
21	10 40 0	−5 6·60	,,	11 50 29·59	+ 2 42·3	,,	+42 52 10·6	9·6814	0·6228	P.	*y*
22	11 16 10	−1 10·70	,,	11 52 31·97	− 6 21·7	,,	+42 57 7·8	9·6784	0·6699	P.	*z*
	11 35 40	−1 9·10	,,	11 52 33·57	− 6 17·1	,,	+42 57 12·4	9·6820	0·6974	S.	*z*
25	10 59 40	−3 21·79	,,	11 58 22·62	− 5 34·4	,,	+43 9 34·1	9·6766	0·6525	P.	*a*
	...	+4 40·07	,,	11 58 22·70	+ 6 4·2	,,	+43 9 33·6	...	...	P.	*z*
27	10 55 30	+ 29·10	,,	12 2 13·49	+ 0 59·2	,,	+43 16 7·7	9·6773	0·6512	P.	*a*
28	10 56 22	+2 22·82	,,	12 4 7·20	+ 3 51·2	,,	+43 18 59·7	9·6787	0·6500	P.	*a*
29	11 5 32	+4 16·78	,,	12 6 1·13	+ 6 14·0	,,	+43 21 22·5	9·6821	0·6714	P.	*a*
	11 7 0	− 35·75	,,	12 6 1·33	− 9 21·2	,,	+43 21 20·2	9·6825	0·6735	P.	*β*
30	10 53 48	+1 14·64	,,	12 7 51·72	− 6 53·2	,,	+43 23 48·2	9·6798	0·6568	P.	*β*
	...	−4 14·88	,,	12 7 51·67	+ 0 42·3	,,	+43 23 51·5	...	...	P.	*γ*

Notes.

May 4.—Frequently interrupted by passing clouds. The comet was earlier compared with W.B. 652, but the R.A. is very discordant. Probably the difference of declination was too great for a trustworthy observation. The Right Ascension in the Radcliffe Catalogue, 1890, differs, however, some ten seconds from W. B. I have no means of determining whether this be due to an error in either catalogue, or to proper motion in the interval, 1890 November 23. May 7.—Definition very bad; star images blurred. May 18.—Moonlight troublesome. June 6.—The observation not considered satisfactory; sky hazy.

Mean Places of Stars of Comparison.

Star's Designation or Authority for Places.	Mean R.A. 1894·0.	Corr. to Apparent R.A.	Mean Declination 1894·0.	Corr. to Apparent δ	Letter of Reference.
	h m s	s	° ′ ″	″	
Paris Catalogue, No. 10304	8 19 17·98	+0·52	− 3 24 26·6	−2·7	*a*
Brad. 1197. Berliner Jahrbuch	8 20 21·81	+0·52	− 3 33 38·8	−2·7	*b*
Glasgow 70, No. 2327, Paris No. 11121	8 57 36·58	+0·81	+ 7 14 0·3	−0·5	*c*
Paris Catalogue, No. 11477	9 14 1·58	+0·96	+13 22 11·9	+1·1	*d*
Glasgow 70, No. 2410	9 15 31·33	+0·97	+13 33 49·3	+1·1	*e*
W.B. (2) IX., No. 450	9 23 32·65	+1·04	+15 50 5·2	+1·6	*f*
Bonn Zones, Vol. VI. +20°, No. 2365	9 36 38·83	+1·16	+20 27 0·9	+2·7	*g*
Paris Cat., No. 11958; Glasgow 70, No. 2524	9 37 26·40	+1·18	+20 40 39·4	+2·7	*h*
W.B. (2), IX., No. 1217	9 59 28·62	+1·35	+27 0 19·6	+4·1	*i*
Bonn Zones, Vol. VI. +27°, No. 1850	10 1 51·03	+1·37	+27 11 10·1	+4·1	*j*
Paris Catalogue, No. 12473	10 5 34·11	+1·40	+28 21 59·6	+4·3	*k*
„ „ 12654	10 14 39·06	+1·46	+29 28 30·9	+4·4	*l*
Leiden, Ast. Ges. Zones, 287, 288	10 23 21·92	+1·53	+32 32 54·7	+5·1	*m*
„ „ „ 169, 281	10 26 29·26	+1·55	+32 30 8·3	+5·0	*n*
Lund, Ast. Ges. Zones, 163	10 37 32·77	+1·63	+35 3 57·3	+5·3	*o*

Star's Designation or Authority for Places.	Mean R.A. 1894·0.	Corr. to Apparent R.A.	Mean Declination 1894·0.	Corr. to Apparent δ	Letter of Reference.
	h m s	s	° ′ ″	″	
Bonn Zones, Vol. VI. + 35, No. 2174	10 36 3·32	+ 1·62	+ 35 4 3·8	+ 5·4	*p*
Lund, Ast. Ges. Zones, 188, 192	10 48 56·92	+ 1·69	+ 36 43 9·4	+ 5·6	*q*
,, ,, ,, 163, 174, 176	10 48 48·25	+ 1·68	+ 37 19 27·5	+ 5·8	*r*
,, ,, ,, 195, 198	10 56 14·84	+ 1·72	+ 37 33 7·6	+ 5·6	*s*
,, ,, ,, 174, 176	10 51 2·86	+ 1·68	+ 37 44 27·9	+ 5·8	*t*
,, ,, ,, 174, 176	10 53 38·25	+ 1·72	+ 38 13 8·3	+ 5·8	*u*
Bonn Zones, Vol. VI. + 38°, No. 2210	11 1 0·88	+ 1·74	+ 38 20 27·2	+ 5·7	*v*
Lund, Ast. Ges. Zones, 174, 176	11 2 30·27	+ 1·73	+ 38 33 43·5	+ 5·8	*w*
W.B. (2) XI., No. 243	11 15 43·08	+ 1·80	+ 40 24 50·0	+ 5·8	*x*
,, ,, 1048	11 55 34·35	+ 1·84	+ 42 49 23·0	+ 5·3	*y*
Bonn Zones, Vol. VI. + 43, No. 2172	11 53 40·85	+ 1·82	+ 43 3 24·1	+ 5·4	*z*
W.B. (2) XI., No. 1183	12 1 42·60	+ 1·81	+ 43 15 3·2	+ 5·3	*α*
W.B. (2) XII., No. 95	12 6 35·30	+ 1·78	+ 43 30 36·2	+ 5·2	*β*
W.B. (2) XII., No. 198	12 12 4·76	+ 1·77	+ 43 23 4·2	+ 5·0	*γ*

Liverpool Observatory:
1894 *November* 6.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. DECEMBER 14, 1894. No. 2

Captain W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

George Cox Bompas, F.G.S., F.R.G.S., 121 Westbourne Terrace, Hyde Park, W.;
Bryan Cookson, Oakwood, Wylam, R.S.O., Northumberland; and
Lieut. Basil Taylor, R.N., H.M.S. *Blake*, North American Station,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Edwin Bare, Ruthven Villa, Hainault Road, Leytonstone (proposed by James Glaisher);
Vincent Joseph Bouton, B.Sc., 9 Lansdowne Terrace, Hampton Wick (proposed by Arthur Cottam);
Henri Deslandres, D.-ès-Sc., Astronome-adjoint à l'Observatoire de Paris (proposed by Captain W. de W. Abney);
Comte A. de la Baume Pluvinel, 7 rue de la Baume, Paris (proposed by Captain W. de W. Abney);
George Darley Lardner, Commissary-General, 6 Princes Road, Wimbledon (proposed by R. A. Gregory);
C. W. D. Perrins, Davenham Bank, Malvern (proposed by the Rev. F. J. Eld);
Charles A. Post, 21 Washington Square, New York, U.S.A. (proposed by Harold Jacoby); and

Charles Roberts, 6 Bramerton Street, King's Road, Chelsea, S.W. (proposed by Adam Hilger).

Mr. J. E. Drower, Mr. W. B. Gibbs, and Mr. H. P. Hollis were appointed Auditors of the Treasurer's accounts for the year 1894.

One hundred and five presents were announced as having been received since the last meeting, including, amongst others—

A series of sixteen memoirs from the *Comptes Rendus*, &c., by M. Deslandres, presented by the Author, and copies on glass of nine spectrum photographs of the solar prominences, &c.; Détermination des constantes pour la réduction des clichés pris à Helsingfors, pour la construction du carte du Ciel, par A. Donner, presented by the Author; Radiant Suns, by Agnes Giberne, presented by the Author; Three volumes, containing a series of drawings of Sun-spots, presented by the Rev. F. Howlett; Publications of von Kuffner's Observatory, Vienna, vol. iv., presented by the Observatory; Lund Observatory Zone Observations $+35°$ to $+40°$, presented by the Observatory; Scheiner's Treatise on Astronomical Spectroscopy, translated, revised, and enlarged by E. B. Frost, presented by Professor Frost; Scheiner, Untersuchungen über den Lichtwechsel Algols, presented by Dr. L. Becker.

A Re-determination of the Epoch Correction and Mean Motion for Hansen's Lunar Tables from Meridian Observations of the Moon, 1750–1892. E. J. Stone, M.A., F.R.S., Radcliffe Observer.

In the present paper it is proposed to apply the views which I hold of the physical bases of the measures of time adopted in practical astronomical work to a re-determination of the epoch constant and mean motion in Hansen's Lunar Tables.

The results of all the meridian observations of the Moon made at Greenwich between 1750 and 1882, and those made at the Radcliffe Observatory, Oxford, from 1880 to 1892, will be included in the discussion.

The residuals give in column (3) of the following table have been taken from Airy's determinations of the mean errors in longitude of Damoiseau's Tables, *Memoirs*, vol. xxix., but they have been corrected for those parts of the differences of the Greenwich sidereal times which correspond to the beginning of the "unit day," which have usually been acknowledged and allowed for, in passing from the data adopted in Carlini's Tables to the data adopted in Le Verrier's Tables; and these corrections have been carried into all the residuals given in column (3).

The residuals, 1847–1892, have been obtained from direct

comparisons between Hansen's Lunar Tables and observations made in the usual manner.

My views on time-measurement are the direct mathematical consequences of the necessary continuity of our measures of time and of length, and the assumed truth of the three following working hypotheses :—

1. The law of universal gravitation.
2. The constancy of the Sun's mass.
3. The uniformity of the rotation of the Earth around its axis.

Sensible constancy during the whole period over which our investigations extend may be understood instead of absolute constancy.

These working hypotheses would have to be abandoned if it could be shown that, subject to the necessary continuity of our measures of time and of length, they led to results inconsistent with the facts of observation.

But, subject to the truth of these working hypotheses, the symbol, f, which expresses the accelerating effects of the Sun's mass, adopted as the unit of mass, at the unit of length, in the unit of time, cannot be changed in evaluating the gravitational effects of the different masses so long as the same units of length and of time are adopted.

To assume otherwise, and that different numerical values, f_1, f_2, f_3, &c., might be assigned to f in the investigation of the disturbing effects of the planetary masses on the motions of *Mercury*, *Venus*, the Earth, and the Moon, would be to assume, in practice, that the law of universal gravitation was not true. And the more accurately the differential equations of motion were formed and integrated with the use of different values f_1, f_2, &c., for f and the more exact the observations, the more evident would become the divergency between the mathematical results thus erroneously obtained and the facts of observation. Different numerical values can be assigned to f in our mathematical work by the adoption of different units of length and of time, but not otherwise. The numerical values which can be assigned to f are necessarily connected with the different units which we can adopt in such a way that $f \propto$ directly as the square of the interval of time which is adopted as the unit, and inversely as the cube of the length which is adopted as the unit.

But if ω denotes the constant angular velocity of the Earth about its axis, the numerical values which can be assigned to ω in our mathematical work are subject to the condition that they vary directly as the interval of time which is adopted as the unit. It follows, therefore, that, whatever unit of time we may adopt, the numerical values which are assignable to the $\sqrt{f}$ and ω in our mathematical work must be such that the ratio $\sqrt{f} : \omega$ is an absolute constant so long as the same unit of length is adopted. If, therefore, in the investigations of the heliocentric motion of the centre of gravity about the Sun we eliminate the

quantity f from our equations by the condition that $f = a^3n^2$, where a is a linear quantity which may, by a proper selection of the unit of length, be made = 1, and n is the coefficient of t in the expression of the heliocentric longitude of the Earth, it follows that the ratio $\omega : n$ is an absolute constant for any possible units of length and of time that we can adopt; and that the angles n and ω can only be found from observation subject to the condition $\frac{\omega}{n}$ is an absolute constant, and we can no more change n in our equations without an alteration of the unit of time than we can change ω or f.

The necessary conditions to preserve the same value of f in the lunar and solar theories when subsidiary conditions such as $f = a^3\mu^2$ are introduced, and μ is taken as the coefficient of t in the expression of the geocentric longitude of the Moon, are usually satisfied by the introduction of the condition that the ratio $\mu : n :: 1 : m$, where m is an absolute constant; and the results thus obtained should be exact, provided the numerical value ultimately assigned to μ is found on the scale of time-measurement fixed by the numerical value ultimately assigned to n; and the value of m is thus deduced from the ratio of two angular velocities referred to the same unit.

And what is true of ω and n will be equally true of Ω and N, if Ω denotes the mean motion of the meridian in right ascension measured from the true equinox, and N the coefficient of t in the expression for the geocentric longitude of the Sun, also measured from the true equinox. We shall have, therefore, in order to find accurate values of Ω and N from observation to introduce the condition that the ratio $\Omega : N$ is an absolute constant, whatever unit of length and of time we may adopt.

The differences between my results and those which have hitherto met with acceptance entirely turn upon the point whether the condition $\frac{\omega}{n}$, an absolute constant, is a fundamental condition which must be satisfied in order that our gravitational investigations can be exact after we have introduced into them the condition $f = a^3n^2$ or $f = n^2$, and $\mu : n :: 1 : m$, m being a constant.

The condition $\frac{\Omega}{N}$, an absolute constant, leads to the condition that Ω may be expressed under the form

$$(2\pi \frac{N}{N_0} + N) = 2\pi + N + 2\pi \frac{N - N_0}{N_0},$$

which cannot, therefore, $= 2\pi + N$ unless N happens to be identically equal to N_0, a definite angle for a definite epoch. For any other adopted angle N, we have, therefore,

$$\Omega_1 = 2\pi \frac{N_1}{N_0} + N_1 = 2\pi + N_1 + 2\pi \frac{N_1 - N_0}{N_0},$$

and therefore

$$\Omega_1 - \Omega = N_1 - N + 2\pi \frac{N_1 - N}{N_0}.$$

Astronomers have hitherto duly allowed for the effects of the term $N_1 - N$, but have overlooked the term

$$2\pi \frac{N_1 - N}{N_0}$$

in the difference $\Omega_1 - \Omega$; and *it was in this way that Hansen determined, from a discussion of observations*, the epoch correction and mean motion adopted in his tables which, if my views are correct, are necessarily defective, because results obtained in terms of one scale of time-measurement fixed by an adopted angle, N, were compared with observational results to obtain which another scale of time-measurement fixed by an adopted angle, N_1, had been employed.

The corrections, δS, given in column (7) of the following table are the effects on the tabular mean longitudes due to the neglect of the terms

$$2\pi \frac{N_1 - N}{N_0},$$

computed from the values N_1 and N used by astronomers before and after 1864. The effects of these terms are certainly important; the only question at issue is whether they are, or are not, necessary if the continuity of our measure of time is to be preserved. I maintain, of course, that they are necessary, and I have simply traced the consequences of their application.

The difference between Hansen's and Le Verrier's values of N is but slight, and can easily and directly be allowed for by the transformation of Hansen's expressions, so far as they depend on the Sun's position, before proceeding to the determination of the constants involved in the periodical terms with the corrected values of the epoch constant ϵ and the mean motion μ.

Reference No.	(1) Years grouped.	(2) Mean Year.	(3) Tabular *minus* Observed D to 1851 H 1848–1892.	(4) Correction to reduce D to H in Mean Longitude.	(5) Correction to D for Hansen's Long Inequalities.	(6) Sum of the three preceding Columns and Hansen – Observed when the Corrections δS are neglected.	(7) Correction for δS usually neglected.	(8) Sum of the two preceding Columns, and Hansen – Observed afforded by Errors in Epoch and Mean Motion.	(9) Hansen *minus* Observed with New Epoch and Mean Motion.
1	1750–1759	1754·5	+ 3″·13	−27″·83	+26″·62	+ 1″·92	−87″·90	−85″·98	−0″·93
2	1755–1764	1759·5	+ 1 31	−25·03	+25·87	+ 2·15	−83·89	−81·74	−0 54
3	1760–1768	1764·0	+ 0·23	−22·51	+24·84	+ 2·56	−80·28	−77·72	+0 01
4	1765–1773	1769·0	− 1·52	−19·69	+23·29	+ 2·08	−76·27	−74·19	−0·31
5	1769–1778	1773 5	− 3·14	−17·14	+21·56	+ 1·28	−72 65	−71·37	−0·96
6	1774–1782	1778·0	− 3·51	−14·57	+19·52	+ 1·44	− 9·04	−67·60	−0·65
7	1779–1787	1783 0	− 3·16	−11·72	+16·94	+ 2·06	−65·03	−62·97	+0·12
8	1783–1791	1787·0	− 3·89	− 9·44	+14·65	+ 1·32	−61·81	−60·49	−0·48
9	1788–1796	1792·0	− 4·62	− 6·56	+11·55	+ 0·37	−57 80	−57·43	−1·27
10	1792–1801	1796·5	− 2·91	− 8·96	+ 8·57	+ 1·70	−54·19	−52·49	+0·20
11	1797–1805	1801·0	− 1·03	− 1·36	+ 5·45	+ 3·06	−50·58	−47·52	+1·70
12	1802–1810	1806·0	− 1·30	+ 1·55	+ 1·85	+ 2·10	−46·56	−44·46	+0·91
13	1806–1815	1810·5	− 1·11	+ 4·18	− 1·46	+ 1·61	−42·95	−41·34	+0·56
14	1811–1819	1815·0	+ 0·42	+ 6 81	− 4·77	+ 2·46	−39·34	−36·88	+1·56
15	1816–1824	1820·0	+ 1·19	+ 9·76	− 8·43	+ 2·52	−35·32	−32·80	+1·78

Reference No.	(1) Years grouped.	(2) Mean Year.	(3) Tabular *minus* Observed D to 1851 H 1848–1892.	(4) Correction to reduce D to H in Mean Longitude.	(5) Correction to D for Hansen's Long Inequalities.	(6) Sum of the three preceding Columns and Hansen—Observed when the Corrections δS are neglected.	(7) Correction for δS usually neglected.	(8) Sum of the two preceding Columns, and Hansen—Observed affected by Errors in Epoch and Mean Motion.	(9) Hansen *minus* Observed with New Epoch and Mean Motion.
16	1820–1829	1824·5	+ 0″·90	+ 12″·41	− 11″·64	+ 1″·67	− 31″·71	− 30″·04	+ 1″·08
17	1825–1833	1829·0	+ 0·93	+ 15·08	− 14·74	+ 1·27	− 28·10	− 26·83	+ 0·82
18	1830–1838	1834·0	+ 1·35	+ 18·06	− 17·99	+ 1·42	− 24·08	− 22·66	+ 1·14
19	1834–1842	1838·0	+ 0·77	+ 20·45	− 20·41	+ 0·81	− 20·87	− 20·06	+ 0·65
20	1839–1847	1843·0	− 0·40	+ 23·44	− 23·17	− 0·13	− 16·86	− 16·99	− 0·13
21	1843–1851	1847·0	− 2·13	+ 25·85	− 25·14	− 1·42	− 13·65	− 15·07	− 1·29
22	1848–1856	1852·0	− 1·50	...	...	− 1·50	− 9·63	− 11·13	− 1·20
23	1852–1860	1856·0	− 2·24	...	...	− 2·24	− 6·42	− 8·66	− 1·82
24	1857–1865	1861·0	− 1·89	...	...	− 1·89	− 2·50	− 4·39	− 1·40
25	1861–1869	1865·0	+ 0·85	...	...	+ 0·85	− 0·54	+ 0·31	+ 0·22
26	1866–1874	1870·0	+ 5·43	...	...	+ 5·43	0·00	+ 5·43	+ 1·49
27	1870–1878	1874·0	+ 7·90	...	...	+ 7·90	0·00	+ 7·90	+ 0·88
28	1875–1883	1879·0	+ 10·37	...	...	+ 10·37	0·00	+ 10·37	− 0·51
29	1879–1887	1883·0	+ 13·16	...	...	+ 13·16	0·00	+ 13·16	− 0·80
30	1884–1892	1888·0	+ 16·99	...	...	+ 16·99	0·00	+ 16·99	− 0·82

A discussion of the residual errors in column (8), with an allowance for the fact that the mean annual residuals refer to the middle and not the commencement of the year, gives for the necessary corrections to epoch, ϵ, and mean motion, μ, the following values :—

$$\delta\epsilon = +49''\cdot994 + 0''\cdot385 = 50''\cdot379$$

$$\delta\mu = -0''\cdot7705$$

the epoch being 1800 Jan 0·0. G.M.T.

The residual errors, for the thirty equations from which the corrections to the epoch and mean motion have been deduced, are given in column (9).

But on account of the use of residuals indirectly deduced from comparisons made through Damoiseau's Tables, I have given as a check the mean annual residuals for all the years 1847–1892 for which I have results available from direct comparisons between Hansen's Tables and observations. It will be seen that, although the observations of the last forty years cannot have been used by Hansen in the deduction of data for the formation of his tables, the agreement between his results and those of observation are remarkably close. The mean of the residual errors in longitude for the years 1847–1892 is only $-0''\cdot32$, and the mean error only $1''\cdot17$.

Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years 1847 *to* 1892, *as computed from Hansen's Tables uncorrected and with the corrected Epoch and Mean Motion determined from the Meridian Observations of the Moon*, 1750 *to* 1892.

Hansen *minus* Observed
(for all the Annual Results available from direct comparison with Hansen's Tables).

Year.	Uncorrected.	Corrected.	Year.	Uncorrected.	Corrected.
	″	″		″	″
1847	+0·51	+1·04	1870	+ 4·65	+0·70
1848	−0·53	+0·04	1871	+ 6·71	+1·99
1849	−1·08	−0·48	1872	+ 7·05	+1·56
1850	−0·97	−0·34	1873	+ 7·95	+1·69
1851	−1·93	−1·27	1874	+ 8·96	+1·93
1852	−1·57	−0·87	1875	+ 9·51	+1·71
1853	−2·18	−1·46	1876	+ 9·45	+0·88
1854	−2·34	−1·59	1877	+ 8·91	−0·43
1855	−1·40	−0·62	1878	+ 7·93	−2·18
1856	−1·51	−0·69	1879	+ 9·29	−1·59
1857	−2·41	−1·56	1880	+10·71	−0·94
1858	−2·61	−1·73	1881	+10·32	−2·10
1859	−2·49	−1·57	1882	+12·45	−0·74
1860	−3·62	−2·67	1883	+14·71	+0·75
1861	−2·95	−1·97	1884	+14·65	−0·08
1862	−2·72	−1·71	1885	+15·20	−0·30
1863	−1·54	−0·49	1886	+15·34	−0·93
1864	+0·12	+0·80	1887	+15·70	−1·34
1865	+1·22	+1·13	1888	+17·68	−0·13
1866	+2·07	+1·21	1889	+17·37	−1·21
1867	+3·35	+1·72	1890	+18·02	−1·33
1868	+3·97	+1·57	1891	+19·30	−0·83
1869	+4·12	+0·95	1892	+19·69	−1·20

The results here obtained are the converse of those which I have annually brought before the Society for some years. In those comparisons between Hansen's Tables and the observations of the Moon I have accepted Hansen's Tables with the epoch and mean motion which he found for observations made during a period when the data of Carlini's Solar Tables were employed; and I corrected the times, t, found as at present to reduce them to the scale for which the values t and μ had been found. In the present investigation I have conversely corrected the times determined, 1750-1864, and reduced them to the present scale of time-measurement, and then re-determined the epoch and mean motion on the scale at present adopted. But as this gives a period of at least forty additional years for the determination of the mean motion, the result may be expected to be more accurately found on its scale than that found by Hansen.

I have not, at present, attempted to correct the determination of the constants involved in the periodic terms. Such a step appears useless until the great fundamental principles at issue in these questions have been definitely settled. But if anyone will assume that the time as now found is absolutely correct, or that the tabular places are correctly referred to the meridian with Le Verrier's value of N, or, in other words, if

$$2\pi \cdot \frac{N - N_0}{N_0} \cdot t$$

is a negligible angle, and the corrections

$$\delta\epsilon = +50''\cdot379$$
$$\delta\mu = -0''\cdot7705$$

are carried into the mean longitude of Hansen's Tables, the tabular results thus obtained will agree very closely indeed with the results of observation.

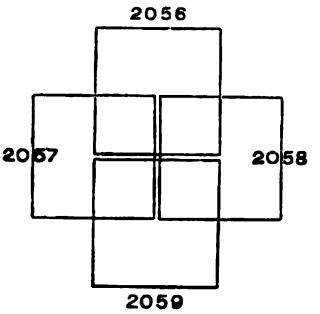
I am engaged in examining the effects of the rejection of one of Hansen's long inequalities, but at present I can only say that if this were done the necessity for the corrections δS is equally apparent. The residual errors are not so small as before, but they are, perhaps, not much larger than are admissible if the old observations are affected, as may be the case, with sensible systematic errors.

Account of the Measurement and Comparison of a Set of Four Astrographic Plates, made at the Royal Observatory, Greenwich. By W. H. M. Christie and F. W. Dyson.

Before commencing the systematic measurement of the astrographic plates it seemed desirable to make a tolerably complete discussion of the measures in one particular case. For this purpose four catalogue plates were taken by Miss Everett on 1894 May 21. Each plate had three exposures of 6^m, 3^m, and 20^s respectively, the guiding star being placed successively at three of the angles of a square formed by spider lines 20′ apart in N.P.D. and R.A. respectively. The 3^m image is thus 20″ south of the 6^m, and the 20^s image (for stars of ninth magnitude and upwards) 20″ due west of the 6^m image. The right ascension, declination, and mean distance of the plate during exposure from the meridian are :—

No. of Plate.	R.A. h m	Declination. °	R. of Meridian. m
2056	16 50	67	70
2057	16 40	68	40
2058	17 0	68	40
2059	16 50	69	20

Thus the plates are arranged as in the accompanying diagram, a quarter of each plate overlapping one quarter of each of the two adjacent plates.



At Professor Turner's suggestion, a glass scale in connection with a viewing microscope was used for the measurement of the photographs, and it was found, as will be seen from the results here given, that this simple and rapid method gave the position of the star's image relatively to the *réseau* lines with sufficient accuracy. It was arranged to use a glass diaphragm with two scales at right angles, divided to $\frac{1}{10}$th of a millimetre (representing 3″ in the sky), which was made by Mr. Simms, the diaphragm being placed in the focal plane of the microscope of the astrographic micrometer. By means of the perpendicular slides

of the micrometer, the star's image is placed accurately at the intersection of the two scales, and the position of the *réseau* lines relatively to it is read off on the two cross-scales by estimation to $\frac{1}{200}$th of a millimetre (0·001 of a *réseau* interval), representing 0″·3 in the heavens. The coordinates of the 6^m and 3^m images of each star were measured both by Miss Everett (A. E.) and Miss Russell (A. R.). The measured places of the stars on two overlapping plates were compared by the method given by Professor Turner in the *Monthly Notices* for 1893 November (vol. liv. pp. 11–25). This method consists in deducing from the measured coordinates of a star on one plate what would be its coordinates on the second had the plates no errors arising from error of setting, of orientation, and differential refraction which were not equally shared by the two plates, the deduced places being then compared with the actual measured places on the second plate, and corrected by means of linear formulæ. If we call x_1 and x_2 the measured coordinate of the same star on the two plates, then from x_1 a quantity x_{12} has been derived from the assumed settings of the plates : this does not differ far from x_2.

The quantities $x_2 - x_{12}$ have been formed for all the separate stars, and it is assumed that these can be represented by the formula

$$ax_2 + by_2 + c.$$

The quantities a, b, c, d, e, f are determined, and the quantities

$$x_{12} + ax_2 + by_2 + c, \qquad y_{12} + dx_2 + ey_2 + f,$$

are the coordinates which the star would have had on the second plate, as given by the measures on the first plate, allowing for the errors of setting, &c., of the two plates.

The constants a, b, c, &c., were determined in several different ways. The results showed :—

1. That it was desirable to use a fairly large number of stars, say forty or fifty.

2. That the stars used for this comparison need not be confined to those which were within a limited distance of the centres of the overlapping plates.

3. That by dividing the stars into four groups—those on the top half, those on the bottom half, those on the left half, those on the right half of the quarter plate—and by taking the means for these four groups, the determination of a, b, c, &c., was practically as accurate as that obtained by employing the method of least squares.

When the plates were compared two and two in this manner, it was anticipated that a and e would vanish, and that b would $= -d$. This amounts to assuming that the only errors not common to the two plates were errors of centring and orientation. When a slight error in the theoretical formulæ of transformation had been corrected (*Monthly Notices*, 1894 June, Supplementary Number, p. 573), the values found for the constants were as follows :—

TABLE I.

Different determinations of the constants connecting two plates.

Plate 2059 to 2057.

Measurer	Exposure m	No. of stars used	*a*	*b*	*c*	*d*	*e*	*f*
A.R.	6	59	+·00017	+·00131	+·0244	−·00102	+·00017	−·1004
A.E.	6	32	+·00014	+·00114	+·0264	−·00095	+·00002	−·1010
A.R.	3	46	+·00031	+·00116	+·0159	−·00102	+·00022	−·1037
A.E.	3	34	+·00032	+·00103	+·0171	−·00106	−·00017	−·1011
	Mean	... ...	+·00025	+·00116		−·00101	+·00006	

Plate 2056 to 2057.

Measurer	Exposure m	No. of stars used	*a*	*b*	*c*	*d*	*e*	*f*
A.R.	6	48	+·00020	+·00172	+·0271	−·00174	+·00003	−·1248
A.E.	6	42	+·00015	+·00158	+·0268	−·00195	+·00017	−·1220
A.R.	3	40	+·00031	+·00166	+·0208	−·00170	−·00005	−·1260
A.E.	3	40	+·00052	+·00162	+·0197	−·00156	−·00016	−·1258
	Mean	... ...	+·00030	+·00165		−·00174	00000	

Plate 2056 to 2058.

Measurer	Exposure m	No. of stars used	a	b	c	d	e	f	
A.R.	6	58	−·00035	+·00022	−·0303	−·00041	−·00006	−·0126	}
A.E.	6	54	−·00015	+·00020	−·0298	−·00021	+·00003	−·0105	}
A.R.	3	46	−·00029	+·00029	−·0231	−·00050	−·00012	−·0129	}
A.E.	3	50	−·00029	+·00025	−·0231	−·00035	−·00009	−·0117	}
	Mean	... ...	−·00027	+·00024		−·00037	−·00006		

Plate 2059 to 2058.

Measurer	Exposure m	No. of stars used	a	b	c	d	e	f	
A.R.	6	68	−·00006	−·00040	−·0271	+·00042	+·00002	+·0289	}
A.E.	6	60	−·00010	−·00035	−·0279	+·00041	−·00003	+·0291	}
A.R.	3	60	−·00007	−·00042	−·0240	+·00033	+·00010	+·0266	}
A.E.	3	56	−·00010	−·00029	−·0255	+·00044	−·00020	+·0289	}
	Mean	... ...	−·00008	−·00036		+·00040	−·00003		

An examination of this table shows—

1. A difference between the values of c as determined from the measures of the 6^m and 3^m images. This arises from different errors in the bisection of the guiding star at the two exposures. There seems also to be a very small difference in the value of f.

The quantities c and f are expressed in decimals of a *réseau* interval (5′), so that 0·001 denotes 0″·3. The quantities a, b, d, e are coefficients of the coordinates of a star, which in the extreme case may multiply quantities as large as 12 *réseau* intervals. Thus an error of 0·0001 in a, b, d, or e may give rise to an error of 0·0012 of *réseau* intervals, or 0″·36.

2. The quantities a and e cannot be taken = 0. The above table shows that a is not zero for 2059−2057, 2056−2057, 2056–2058: this may possibly arise from tilt in the plates. But the main part of b and d, as they are nearly equal and of opposite sign, seems to arise from difference of orientation error. The value of this difference in angular measure is (irrespective of sign) 4′ 43″, 1′ 18″, 5′ 50″, 1′ 3″ for the four comparisons.

3. The discordances between the values of the constants as given by the different measurers seem to be rather large in some cases, but it should be noticed that the discordances near the mean of the stars compared are much smaller. Thus, in 2059–2057, $c+7a+7b$, as determined by A.R. and A.E., only differ by ·0006 for the 6^m exposure, and by ·0004 for the 3^m exposure, although c as determined by the two differs by ·0020 and ·0012.

The sum of the constants a, b, d and e for a closed ring of plates ought to be zero. Changing the sign in the second and fourth case, so as to give constants for reducing plate 2059 to 2057, 2057 to 2056, 2056 to 2058, and 2058 to 2059, we obtain −·00024, +·00011, −·00004, +·00003 for the sum of the constants a, b, d and e respectively.

The discordances seem to arise from accidental errors in the measurement, and irregularities in the photographic image. The effect of these will be diminished if the means of the measures of the 6^m and 3^m images are considered as the coordinates of the star. In this way both images are used, and hardly any additional work is given to the computer beyond taking the means. A direct comparison has also been made—

1. Between the measures of the same image by the two measurers.

It was found that the personality of the measurers was very small, if at all appreciable. As a mean of 850 measures,

$$\text{AE}-\text{AR} = -0''.1 \text{ in the horizontal coordinate}$$
$$= -0.2 \text{ in the vertical coordinate.}$$

The mean discordance between the measures of the same image by the two observers was found to be $\pm 0''.36$.

2. Between the measures of the 6^m and 3^m images by the same observer : the mean discordance was in this case $\pm''\cdot36$. There was just the same range as in the measures of the same star by the two measurers.

3. The mean discordance between a measured coordinate of a star on one plate and its coordinate computed from the corresponding measure on an overlapping plate was found to be $\pm''\cdot45$. The fact that this is so slightly in excess of $\pm''\cdot36$, the mean discordance between the measures of the same image by the two measurers, shows the validity and accuracy of the method adopted for the comparison of overlapping plates.

The following table is given to exhibit the accordance between the measures of different measurers of images of different exposures and of images on different plates :—

There are eight different measures to be compared. Miss Everett and Miss Russell's measures on plate 2057 of the 6^m images are given directly. From their measures of the 6^m images on plate 2059, the coordinates on plate 2057 were deduced by application of the constants given in Table I. Similarly from their measures of the 3^m images on plate 2059 coordinates on plate 2057 were deduced. Finally, the mean difference between the coordinates of the 6^m and 3^m images was applied to the latter. The mean of the eight different values was taken, and the discordances formed.

Columns 1 and 2 are the approximate coordinates of a star on plate 2057, given in *réseau* intervals, and measured from the centre of the plate.

Columns 3, 4, 5, 6 are the discordances from the mean of Miss Russell's and Miss Everett's measures of the R.A. coordinate of the 6^m and 3^m images on plate 2057. Columns 7, 8, 9, 10 refer to corresponding measures on plate 2059. The remaining eight columns give similar discordances for the other coordinate.

TABLE II.

Comparison of Different Measures on Two Plates.

A Coord. on 2057.	B Coord. on 2057.	*Discordance of A Coordinate from Mean of 8.* 2057 A.R. 6^n.	2057 A.E. 6^m.	2057 A.R. 3^m.	2057 A.E. 3^m.	2059 A.R. 6^m.	2059 A.E. 6^m.	2059 A.R. 3^m.	2059 A.E. 3^m.	*Discordance of B Coordinate from Mean of 8.* 2057 A.R. 6^m.	2057 A.E. 6^n.	2057 A.R. 3^m.	2057 A.E. 3^m.	2059 A.R. 6^m.	2059 A.E. 6^m.	2059 A.R. 3^m.	2059 A.E. 3^m.
+ 2·8	− 0·6	−″·21	+″·09	−″·01	−″·61	+″·39	+″·39	−″·01	−″·01	+″·01	+″·31	+″·21	+″·21	+″·01	+″·01	−″·39	−″·39
3·3	0·2	+·83	+·23	+·43	−·77	+·23	....	+·13	−1·07	−·15	−·45	−·85	−·55	+1·35	...	+·65	...
5·1	0·2	+·10	−·50	...	...	+·40	...	...	...	+·10	−·20	...	...	+·10	...	...	...
5·7	1·1	−·07	−·07	−·17	−·17	−·07	...	+·43	+·13	−·37	−·07	−·47	−·17	−·07	...	+·43	+·73
12·4	0·6	−·59	−·29	−·09	+·51	−·29	+·31	−·09	+·51	−·36	−·06	+·14	−·46	+·24	−·36	+·14	+·74
12·5	− 0·6	−·34	−·34	+1·06	−·14	−·04	−·34	+·16	...	−·04	−·34	+·16	−·14	+·26	−·04	+·16	...
0·4	+ 0·4	−·50	−·20	·00	+·60	+·10	...	·00	...	−·60	·00	+·50	−·40	+·60	...	−·10	...
8·9	0·2	−·18	−·48	+·02	+·62	−·18	−·48	−·28	+·92	−·64	−·34	−·44	−·14	−·04	+·26	+·76	+·76
10·1	0·6	−·18	−·48	−·58	+·62	−·18	−·18	+·32	+·62	+·05	−·55	−·05	+·25	+·05	−·25	−·05	+·55
10·6	0·3	+·15	−·45	...	...	−·15	+·45	...	...	+·37	−·83	...	...	+·07	+·37	...	...
0·7	1·9	−·30	+·00	−·40	−·40	+·60	...	+·50	...	·00	+·30	+·20	+·50	−·30	...	−·70	...
3·2	1·9	+·14	+·14	+·34	+·34	−·46	...	+·04	−·56	+·61	+·61	+·81	+·51	−·59	...	−·99	−·99
4·6	1·3	+·12	−·18	+·02	+·02	−·48	...	+·52	...	+·30	−·30	−·10	−·70	·00	...	+·80	...
6·0	1·4	+·09	+·09	−·61	−·31	+·09	+·09	+·29	+·29	+·31	−·29	−·09	+·21	+·01	−·29	−·09	+·21
8·6	1·7	−·30	...	...	...	+·30	...	...	...	−·15	...	...	...	+·15	...	...	...
1·2	2·7	−·05	−·05	−·45	−·45	+·55	...	+·45	...	−·25	+·05	−·35	−1·25	+1·25	...	+·55	...
1·5	2·6	+·16	−·44	−·24	+·36	−·14	−·14	+·36	+·06	+·01	−·89	+·21	−·39	+·91	−·29	+·51	−·09
5·5	2·8	+·24	+·24	−·16	+·14	+·24	−·36	−·16	−·16	−·29	−·59	−·39	−·39	+·31	+·31	+·51	+·51
5·8	2·7	+·48	+·48	+·38	−·52	+·18	−·12	+·38	+·08	−·21	+·39	+·29	+·29	+·09	+·09	−·01	−·91

A Coord. on 2057.	B Coord. on 2057.	*Discordance of* A *Coordinate from Mean of* 8. 2057 A.R. 6m.	2057 A.E. 6m.	2057 A.R. 3m.	2057 A.E. 3m.	2059 A.R. 6m.	2059 A.E. 6m.	2059 A.R. 3m.	2059 A.E. 3m.
7·6	2·6	−″·33	+″·87	+″·17	+″·17	−″·33	−″·33	+″·17	−″·43
8·2	2·8	−·56	+·04	+·24	+·24	−·56	+·04	−·36	−·06
+ 8·3	2·3	−·59	+·01	+·21	+·21	−·89	+·31	−·09	+·81
− 1·7	3·6	−·29	−·59	−·39	−·39	+·61	+·31	−·09	+·81
− 1·4	3·5	+·20	+·20	...	...	−·40	...	...	...
+ 3·2	3·2	+·61	+·91	+·21	−·09	−·59	−·29	−·39	−·39
5·4	4·0	+·12	...	+·28	...	+·12	...	+·02	...
11·4	3·2	−·50	−·20	·00	+·30	−·20	...	+·60	...
+ 10·7	3·8	−·30	...	...	...	+·30	...	...	...
− 1·7	4·7	+·23	+·23	−·77	−·47	−·37	...	+1·03	+·13
+ 4·9	4·9	+·19	+·19	−·21	+·09	+·19	...	−·21	−·21
6·6	4·7	+·50	+·50	−·50	−1·10	+·20	+·20	+·10	+·10
8·7	4·3	−·14	+·46	−·24	−·24	−·14	−·14	+·06	+·36
8·8	4·5	+·39	−·51	−·01	+·59	−·21	+·09	−·31	−·01
12·8	4·7	+·30	...	...	...	−·30	...	...	...
1·6	5·3	+·39	+·09	−·01	+·29	+·09	...	−·31	−·31
3·0	5·2	+·55	+·25	−·25	−·55	+·55	...	−·55	...
6·5	5·2	+·19	+·49	+·09	+·39	−·11	−·11	−·51	+·09
7·1	5·1	+·15	+·15	−·55	+·35	+·15	...	−·25	...
+ 10·7	5·5	+·31	+·31	−·69	−·03	−·29	−·29	+·51	+·21
− 0·6	6·1	−·14	+·16	−·24	+·06	−·14	+·16	+·06	+·06

A Coord. on 2057.	B Coord. on 2057.	*Discordance of* B *Coordinate from Mean of* 8. 2057 A.R. 6m.	2057 A.E. 6m.	2057 A.R. 3m.	2057 A.E. 3m.	2059 A.R. 6m.	2059 A.E. 6m.	2059 A.R. 3m.	2059 A.E. 3m.
7·6	2·6	+″·01	+″·01	+″·21	+″·21	+″·31	−″·29	−″·39	−″·09
8·2	2·8	+·24	+·24	+·14	+·14	+·24	−·36	−·16	−·46
+ 8·3	2·3	−·33	+·27	+·17	+1·07	−·03	−·33	−·43	−·43
− 1·7	3·6	+·42	+·12	−·28	−·58	+·42	−·18	+·02	+·02
− 1·4	3·5	·00	·00	...	...	·00	...	...	...
+ 3·2	3·2	+·31	+·31	−·09	−·09	+·01	−·29	−·09	−·09
5·4	4·0	+·65	...	−·35	...	−·55	...	+·25	...
11·4	3·2	+·15	+·45	−·25	−·25	+·15	...	−·25	...
+ 10·7	3·8	+·15	...	...	...	−·15	...	...	...
− 1·7	4·7	−·16	−·16	−·26	+·04	−·76	...	+·94	+·34
+ 4·9	4·9	+·23	+·23	+·13	−·17	−·67	...	+·13	+·13
6·6	4·7	+·16	−1·04	+·06	−·54	+·46	+·46	+·36	+·06
8·7	4·3	−·03	+·27	+·17	+·47	−·03	−·33	−·43	−·13
8·8	4·5	−·03	−·03	+·17	+·17	+·27	−·33	+·47	−·73
12·8	4·7	+·60	...	...	...	−·60	...	...	...
1·6	5·3	+·57	−·03	+·77	+·17	−·33	−·63	−·13	−·43
3·0	5·2	+·15	−·15	+·05	+·05	+·15	...	−·25	...
6·5	5·2	+·46	+·46	−·24	+·36	−·44	−·14	+·06	−·54
7·1	5·1	+·20	−·10	−·20	+·10	−·40	...	+·40	...
+ 10·7	5·5	+·31	−·29	−·09	−·69	+·31	+·01	+·51	−·09
− 0·6	6·1	+1·14	−·36	−·16	−·16	−·06	−·36	−·46	+·44

A Coord. on 2057.	B Coord. on 2057.	Discordance of A Coordinate from Mean of 8. 2057 A.R. 6m.	2057 A.E. 6m.	2057 A.R. 3m.	2057 A.E. 3m.	2059 A.R. 6m.	2059 A.E. 6m.	2059 A.R. 3m.	2059 A.E. 3m.	Discordance of B Coordinate from Mean of 8. 2057 A.R. 6m.	2057 A.E. 6m.	2057 A.R. 3m.	2057 A.E. 3m.	2059 A.R. 6m.	2059 A.E. 6m.	2059 A.R. 3m.	2059 A.E. 3m.
+ 0·7	6·7	+ ″·06	+ ″·36	− ″·64	− ″·64	+ ″·66	″ ...	+ ″·26	− ″·04	− ″·11	− ″·41	− ″·21	− ″·21	+ ″·49	″ ...	+ ″·69	− ″·21
1·4	6·2	+ ·00	...	...	...	·00	...	...	...	+ ·30	...	...	...	− ·30	...	...	...
5·3	6·9	− ·25	− ·25	− ·15	+ 1·05	− ·25	+ ·05	− ·85	+ ·65	+ ·61	− ·29	+ ·21	− ·09	− ·29	− ·59	+ ·21	+ ·21
8·6	6·6	− ·36	− ·06	− ·16	+ ·74	− ·06	− ·05	− ·16	+ ·14	+ ·27	+ ·57	+ ·17	− ·43	− ·03	+ ·27	− ·43	− ·43
0·3	7·2	− ·30	...	...	...	+ ·30	...	...	...	− ·15	...	...	...	+ ·15	...	...	...
1·0	7·8	+ ·30	− ·30	+ ·20	− ·10	+ ·60	...	− ·70	...	+ ·70	+ ·10	− ·30	− ·30	+ ·10	...	− ·30	...
4·5	8·2	+ ·15	...	...	...	− ·15	...	...	...	+ ·30	...	...	...	− ·30	...	...	...
5·8	8·7	+ ·37	− ·53	...	...	+ ·67	− ·53	...	...	− ·08	− ·38	...	...	+ ·52	− ·08	...	...
5·9	8·8	+ ·10	+ ·10	...	...	− ·20	...	...	...	·00	− ·60	...	...	+ ·60	...	...	...
9·2	8·3	− ·15	...	...	...	+ ·15	...	...	...	− ·45	...	...	...	+ ·45	...	...	...
+ 3·0	9·9	+ ·15	− ·15	...	...	+ ·15	− ·15	...	...	·00	− ·60	...	...	·60	·00	...	...
− 0·8	10·2	+ ·35	− ·25	+ ·25	− ·35	+ ·05	+ ·35	− ·35	− ·05	+ ·35	− ·25	− ·65	− ·35	+ ·35	+ ·05	+ ·85	− ·35
+ 4·6	10·4	− ·21	− ·21	− ·31	...	+ ·09	+ ·69	+ ·59	...	− ·67	− ·07	+ ·43	...	+ ·23	− ·07	+ ·13	...
− 1·6	12·9	+ ·54	+ ·54	− ·46	+ ·14	− ·06	− ·06	− ·46	− ·16	− ·31	− ·61	+ ·79	− ·41	+ ·29	− ·31	+ ·49	− ·11
+ 7·7	12·6	− ·24	+ ·36	− ·14	− 1·04	+ ·96	+ ·36	− ·14	− ·14	+ ·35	− ·85	+ ·85	− ·65	+ ·65	+ ·05	+ ·25	− ·65
8·6	12·3	+ ·44	+ ·44	− ·36	− ·66	+ ·44	+ ·44	− ·36	− ·36	+ ·41	− ·49	− ·29	− ·59	+ ·41	+ ·41	+ ·31	− ·29
1·8	13·4	+ ·46	− ·14	+ ·66	+ ·66	− ·14	− ·74	− ·24	− ·54	− ·55	+ ·05	+ ·55	+ ·25	+ ·05	− ·25	+ ·55	− ·65
+ 10·5	+ 13·2	− ·14	+ ·46	− ·54	− ·24	+ ·46	− ·14	+ ·36	− ·24	+ ·76	+ ·16	+ ·36	+ ·36	+ ·16	− ·14	− ·24	− 1·44
...	...	...	...	...	...	...	...	...	...	− ·15	...	...	...	+ ·15	...	...	...
Mean discordance		± ·29	± ·30	± ·31	± ·38	± ·30	± ·27	± ·30	± ·32	± ·30	± ·33	± ·31	± ·36	± ·31	± ·25	± ·38	± ·43

These discordances seem somewhat large in some cases, but it is to be remarked that they were obtained from the first measures made with the glass scale, and that none have been rejected, though later examination showed that they were sometimes rather rough in consequence of the want of familiarity of the measurers with their instruments. Nor has any correction been applied for the errors of *réseau*, or for distortion. Considering that these discordances are derived from the comparison of measures on two plates, they seem to show that a satisfactory degree of accuracy can be obtained by the simple method of measurement used.

On the Proper Motions of Three Stars in the Constellation Ophiuchus. By W. T. Lynn, B.A.

In the *Monthly Notices* for 1870 November I gave the proper motions, deduced from Airy's Greenwich Catalogues, of the double star 36 (A) *Ophiuchi* and of a star which in *Flamsteed* is the 30th catalogued in the constellation *Scorpio*, and is therefore called 30 *Scorpii* in Baily's *Flamsteed*, though Baily notes that it should have been included by *Flamsteed* in the constellation *Ophiuchus*, and it is therefore so arranged in the B.A.C., where it is given (without a constellation number) as No. 5813. In the Twelve-year Catalogue and in the two Seven-year Catalogues (it does not appear in the Six-year or in the Nine-year) Flamsteed's number, 30 *Scorpii*, is retained ; but in the Ten-year Catalogue (in which it is No. 2696) it is called in the text *Bradley* 2179.

I have thought it would be worth while to supplement my former paper by computing the proper motions of these stars from the later Greenwich Catalogues, and here set down all the places of the three which are given in them, from the first Seven-year to the Ten-year.

Authority.	Epoch.	A^1 Ophiuchi. R.A.	No. of Obs.	A^2 Ophiuchi. R.A.	No. of Obs.	Bradley 2179. R.A.	No. of Obs.
		h m s		h m s		h m s	
7-year for	1860	17 6 44·47	12	17 6 44·67	9	17 7 37·18	8
7-year ,,	1864	17 6 59·27	3	17 6 59·33	1	17 7 51·80	2
9-year ,,	1872	17 7 28·583	5	17 7 28·816	3	...	...
10-year ,,	1880	17 7 58·105	10	17 7 58·314	8	17 8 50·846	4
		N.P.D.		N.P.D.		N.P.D.	
7-year for	1860	116° 23′ 35″·06	12	116° 23′ 31″·26	9	116° 20′ 25″·21	8
7-year ,,	1864	116 23 59·08	3	116 23 55·01	1	116 20 47·77	2
9-year ,,	1872	116 24 42·45	5	116 24 38·08	2	...	...
10-year ,,	1880	116 25 31·03	11	116 25 25·93	9	116 22 17·17	4

From these places we obtain the following annual variations :—

		A¹ Ophiuchi. R.A.	N.P.D.	A² Ophiuchi. R.A.	N.P.D.	Bradley 2179 R.A.	N.P.D.
		s	″	s	″	s	″
From the years	1860–64	+3·700	+6·00	+3·665	+5·94	+3·655	+5·64
,,	1864–72	+3·664	+5·42	+3·686	+5·38	[1864–1880]	
,,	1872–80	+3·690	+6·07	+3·687	+5·98	+3·690	+5·59
From whole period	1860–80	+3·682	+5·80	+3·682	+5·73	+3·683	+5·60

Now the geometrical precessions for the three stars are, for 1860, in RA. + 3ˢ·718, + 3ˢ·718, and + 3ˢ·717 respectively, in N.P.D. + 4″·62, + 4″·62, and 4″·54 ; and for 1880, in RA. + 3ˢ·720, + 3ˢ·720, and + 3ˢ·719, in N.P.D. + 4″·514, + 4″·514, and + 4″·439, the means of which may safely be used in obtaining the proper motions.

	In R.A. Annual Variation.	Annual Precession.	Resulting Annual Proper Motion.
	s	s	s
A¹ Ophiuchi	+3·682	+3·719	−0·037
A² Ophiuchi	+3·682	+3·719	−0·037
Bradley 2179	+3·683	+3·718	−0·035

	In N.P.D. Annual Variation.	Annual Precession.	Resulting Annual Proper Motion.
	″	″	″
A¹ Ophiuchi	+5·80	+4·57	+1·23
A² Ophiuchi	+5·73	+4·57	+1·16
Bradley 2179	+5·60	+4·49	+1·11

These values of the proper motions would seem to be entitled to considerable confidence. Those which I obtained in 1871 by comparing the places in the Greenwich Twelve-year Catalogue with the New Seven-year for 1864 were, in RA. − 0ˢ·029, − 0ˢ·043, and − 0ˢ·042 respectively, and in N.P.D. + 1″·20, + 1″·05, and + 1″·17 ; those adopted from Auwers in the Greenwich Ten-year Catalogue are, in R.A. − 0ˢ·039, − 0ˢ·039, and − 0ˢ·039, and in N.P.D. + 1″·138, + 1″·138, and + 1″·134. What makes these stars so especially interesting is the circumstance that the third, distant from the first two, which form a pair, by about 12′ 21″ in a great circle, partakes with them in the same large proper motion, amounting to about 1″·27 in a great circle.

Perhaps I may be allowed to add that I have compared the places of a considerable number of stars for which no proper motions are given in the Ten-year Catalogue with the corresponding places in the Twelve-year, and all that I have examined are small, with the exception of *Piazzi* III 170, for which I find the annual proper motion in RA. + 0ˢ·005 and in N.P.D. + 0″·145,

both smaller than those assigned in the B.A.C., the latter considerably so, the proper motion in N.P.D. there given amounting to + 0″·25.

Blackheath:
1894 *December* 7.

A Comparison of some Places of Stars observed at the Sydney Observatory with the Places of the same Stars as given in the Cape Catalogue, 1880. By H. P. Hollis.

The stars used in this comparison are contained in the latest publication from the Sydney Observatory, which was published in 1893, and gives the results of meridian observations made in the years 1879, 1880, 1881, in the form of annual catalogues for these years.

From these annual catalogues a catalogue has been formed for epoch 1880 of about 300 stars, all of which have been observed at least three times in either element, and only places which depend on at least three observations have been used in this comparison.

The places thus found have been compared with the places given in Mr. Stone's Cape Catalogue for epoch 1880, and Table I. gives the result of this comparison, the stars being arranged in order of R.A. and divided into hourly groups. The figures in columns 3 and 5 give the simple means of such groups.

TABLE I.

	R.A.		N.P.D.			R.A.		N.P.D.	
Limits of R.A.	No. of Stars.	Difference Sydney−Cape ×sin N.P.D.	No. of Stars.	Difference Sydney−Cape.	Limits of R.A.	No. of Stars.	Difference Sydney−Cape ×sin N.P.D.	No. of Stars.	Difference Sydney−Cape.
h h		s		″	h h		s		″
0–1	7	+0·080	5	+0·33	12–13	14	+0·026	11	−0·13
1–2	7	+0·058	8	+0·33	13–14	23	+0·055	22	−0·76
2–3	10	+0·140	9	+0·38	14–15	21	+0·116	20	−0·36
3–4	20	+0·224	20	−0·04	15–16	11	−0·054	10	−0·04
4–5	13	+0·202	13	+0·37	16–17	18	+0·055	18	−0·65
5–6	16	+0·098	16	+0·89	17–18	8	−0·011	8	+0·05
6–7	11	+0·082	10	+0·85	18–19	3	−0·050	3	+1·26
7–8	15	+0·093	14	−0·11	19–20	1	−0·030	1	+2·68
8–9	15	+0·041	15	+0·73	20–21	10	+0·006	10	−0·44
9–10	17	+0·015	16	+0·47	21–22	9	−0·001		−0·36
10–11	20	+0·013	20	+0·52	22–23	9	+0·044	9	+0·03
11–12	18	−0·015	16	−0·17	23–0	5	+0·053	5	+0·42

This table calls for little comment. In many cases the number of stars in a group is too few to eliminate accidental errors. To form the next table the stars were arranged in order of N.P.D., divided into groups of about ten, and the weighted means of these groups taken, each difference being weighted according to the usual formula:

$$\frac{4mn}{m+n+\frac{1}{2}mn}.$$

TABLE II.

Differences arranged in order of N.P.D. and divided into groups of approximately ten stars. The weighted means of such groups are given.

	R.A.				N.P.D.		
Approx. N.P.D. of group.	No. of Stars.	Wt.	Diff. of R.A. (S.−O.) ×sin N.P.D.	Aprox. N.P.D. of group.	No. of Stars.	Wt.	Diff. of N.P.D Sydney−Cape.
° ′			s	° ′			″
63 37	11	103	+0·049	63 42	9	41	+0·35
69 36	10	98	+0·025	69 36	10	43	+0·70
76 8	10	92	−0·004	76 32	9	42	+1·00
80 15	10	93	−0·003	80 15	10	51	+0·48
82 37	11	104	−0·019	82 44	10	60	+1·47
87 21	10	85	+0·008	87 21	10	49	+0·77
91 30	11	102	+0·013	91 34	10	58	+0·61
97 42	10	94	+0·018	97 42	10	65	+0·81
102 28	10	97	+0·038	102 28	10	58	+0·73
107 47	10	76	+0·042	107 44	9	43	+0·44
113 56	10	80	+0·053	114 1	9	55	+0·04
118 32	10	56	−0·008	118 32	10	52	+0·63
119 50	10	51	+0·056	119 50	10	51	+0·13
120 14	9	49	+0·070	120 14	9	45	−0·31
120 52	10	52	+0·142	120 52	10	51	−0·07
121 49	10	50	+0·070	121 49	10	51	+0·03
123 4	10	55	+0·110	123 4	10	50	−0·38
124 12	10	53	+0·049	124 12	10	54	−0·24
124 50	10	58	+0·143	124 50	10	50	+0·45
125 47	10	51	+0·225	125 47	10	53	+0·20
126 28	10	44	+0·187	126 28	10	48	+0·67
131 21	10	46	+0·126	131 21	10	48	−0·00
135 13	8	40	+0·085	135 3	10	55	−0·51
137 28	10	51	+0·038	137 23	9	42	−0·41
141 29	10	49	+0·124	141 29	10	51	−1·18
146 7	10	49	+0·086	146 7	10	53	−1·38
150 25	10	49	+0·036	150 25	10	56	−1·09
153 19	10	47	+0·296	153 16	9	45	−0·34
159 20	11	81	+0·054	159 49	10	73	−0·71

It will be seen that the differences of N.P.D. are comparatively large, but that there is a decided sequence, which is more obvious from Table III., where the means of the preceding results are taken in groups of five.

TABLE III.

Means of Differences arranged in order of N.P.D. and taken in groups of 50 Stars.

Approx. Mean N.P.D. of group.	Difference of R.A. Sydney−Cape ×sin N.P.D.	Difference of N.P.D. Sydney−Cape.	Correction of the form $+1''{\cdot}576 \times \sin zd$ Sydney.
° ′	s	″	″
74 27	+0·010	+0·83	+1·20
97 22	+0·024	+0·69	+0·73
118 41	+0·061	+0·09	+0·14
123 56	+0·121	+0·01	−0·00
134 24	+0·109	−0·30	−0·29
152 24	+0·074	−0·89	−0·74
General Mean	+0·055	+0·09	

The latitudes of Sydney and of the Cape happen to be nearly identical, each being approximately 33° 54′. The N.P.D. of the fourth group in Table III. is therefore nearly that of the zenith. From the mean of this group in N.P.D. it may be inferred that the difference of the adopted latitudes of Sydney and of the Cape is not far from the truth. The means of the other groups seem to point to the want of an instrumental correction, depending on the zenith distance, to the observations of one or the other catalogues. No correction of this kind was applied to the Sydney observations, but determinations of horizontal flexure by the collimators gave a mean value for the flexure constant of $1''{\cdot}576$. The values of a correction of the form $+ k \sin z.d$ with the above value of k, applicable to the Sydney observations of zenith distance, and therefore applicable with changed sign to these differences, are given in the last column of Table III.

Remarks on Three Volumes of Sun-spot drawings presented to the Society. By Rev. F. Howlett, M.A.

I have the honour of requesting the Society to accept what will, probably, be the *final instalment* of my solar drawings. Many thousands of spots great and small are therein depicted with the greatest care and, let me say, conscientiousness, of which I was capable.

The series, more or less continuous, extends over a period of about five-and-thirty years, and I may truly say the work has been a labour of love and of the deepest interest. I imagine (if I may say so without arrogance) that no such series of hand-

drawings, showing the minute details of the configurations and changes of the solar spots, exists.

If in this respect I am in error, I shall loyally yield the palm of superiority to any other brother observer, whether in England or any other part of the world.

Since the application of the marvellous and invaluable art of *photography* to celestial phenomena of every description, I have sometimes wondered whether, with the view of advancing any real knowledge of the Sun, it was worth my while to continue such a series of drawings; and this has, for one reason, been the cause of very considerable gaps in the record. But encouraged by the plea on behalf of hand drawings of solar phenomena, made in an address to the members of the Royal Institution, a few years ago, by the late admirable and lamented Father Perry, I persevered in the work. Moreover, whilst an almost unbroken daily record of the solar disc on a small scale is preserved at our great National Observatory at Greenwich, it is only, I believe, at rare intervals that astronomy is enriched and instructed by such splendid details of the photosphere, faculæ, and solar spots as are furnished by the photographs of Professor Janssen more especially; though, even in them, the sharp distinction existing between the umbræ and penumbræ is by no means satisfactorily shown. There is sometimes, in fact, no difference manifested at all.

I would now take this opportunity of saying that the main object I have had in view in continuing this series of drawings for so many years—through four periods of maximum solar spot activity and three of minimum activity—has been to test the theory first put forth by Professor Wilson, of Glasgow, as recorded in the *Philosophical Transactions* for the years 1774 and 1783. You all know what that theory is, as maintained in the *Transactions* with what was intended to be the most scrupulous care and attention, though, I cannot but now feel certain, with very imperfect instrumental means and appliances.

What these were is fully described in the *Philosophical Transactions* to which I have just alluded. Wilson's theory is, that owing to the way in which (according to his ideas) the penumbra in a spot *shelves down* towards the umbra of the same, the portion of the penumbra nearest to the Sun's centre will grow perspectively narrower and narrower, causing the umbra, which might be really *central* in the spot, to appear no longer central, but to lie close to the inner edge of the spot.

Now this, of course, *would* be the case if the spots were of that deeply depressed *crateriform* nature which almost all writers on physical astronomy have described them as possessing, but which my observations, made under most charmingly perspicuous conditions, have in almost every instance refuted. Some few spots, indeed, when lying close to the Sun's limb have appeared to favour slightly the Wilsonian hypothesis; but, as Mr. Turner (now Savilian Professor at Oxford) remarked to

me last year in a letter, "one ought to know the *history* of a spot," meaning, "had it been duly ascertained whether or not the umbra of a spot under discussion to test the theory was *really central* or otherwise suitable for such an investigation?" And oftentimes I have found that such a knowledge of their history refuted the testimony to the Wilson theory which an isolated observation seemed to afford. Several such instances will be found in the eight volumes of my drawings.

It is, I believe, generally known that my method of observing the Sun is by projecting the solar image on a screen, placing the latter at such a distance from the eye-piece of the small refractor of 3 inches aperture as shall, with a magnifying power of 80 linear, produce an image of 32 inches in diameter, or about one inch to one minute of celestial arc, though I frequently scrutinise the spots with higher powers producing an image of twice that diameter, as well also as by direct vision with the aid of a Dawes' solar eye-piece.

I cannot too strongly recommend this use of a screen and a small handy refractor, which, with a light shutter adapted to a chamber window, can in a moment be applied for an observation. I have here a photograph of such a shutter, with its appliance of vulcanised indiarubber for clasping the tube of the telescope and keeping out all extraneous light.

I will not on this occasion weary the Fellows with any general description of the contents of these volumes. Those who are interested in the subject of which they form illustrations can, at their leisure, honour them with their attention. There is an index of the spots at the commencement of each volume, wherein are specified those instances which distinctly militate against the Wilsonian theory, as well as those which seem to favour it. There are in the three volumes presented to-day no less than fifty of the former, and only nine of the latter, the majority, if not indeed all of them, being really of no real worth on the Wilsonian side, because, as I have said, the umbræ were shown not to have been *central*.

The theory, in fact, will simply stand or fall by careful and sufficiently prolonged observation, which few, unfortunately, have had the time or disposition to carry out. But, so far as they have been able to do so, both Professor Spörer, of Munich, the late lamented Father Perry, Mr. Cowper Ranyard, the late Mr. Whipple, of the Kew Observatory, and several of my own private friends who have witnessed the behaviour of spots near the limb of the Sun are satisfied that the Wilsonian theory that the spots are funnel-shaped depressions is entirely erroneous.

Moreover, as I stated in a paper which I read before the British Association last year at Nottingham, by the courtesy of the Astronomer Royal and the staff under his administration I was allowed to institute a comparison between the testimony afforded by my own drawings and that of the photographic pictures there accumulated; and I think I may say in

every case I was borne out in my contention that the spots can in no sense be called cavernous. Nay, I make bold to say, that instead of the penumbra of a spot possessing *shelving sides*, sloping down towards the umbra, it (the penumbra) presents a *convex* surface ; that is to say, a curve conformable to the general contour of the solar orb.

Observation leads me to the conviction that the photospheric stratum (save where faculæ occur) consists of merely one layer of the so-called "rice-grain" entities—say about 1000 miles at most in thickness—in close contiguity to the subjacent penumbra ; which, again, can possess no greater thickness than the photosphere, or the umbræ (whose depth I do not profess to estimate) could not be seen *central* in the penumbræ (as I assert they do) when very near the limb. By "very near" I mean not more than some 40 or even 30 seconds only of arc.

Lastly, in contravention of statements put forth on high authority, no spot, however large, or supposing it to have ever so shelving sides, could possibly present the appearance of a *notch* when passing round the limb, but only the slightest possible *flattening* of the sphere at that point, unless indeed the spot were accompanied by a most abnormal and extraordinary piling up of facular matter north and south (but not at the same time east or west) of the penumbra. But this I have never myself witnessed, save in one rather doubtful case on 1862 August 4, as shown in sheet No. 86 of vol. ii.

The appearance of a notch has occasionally been seen in a *photograph* ; but that was simply in consequence of the lack of sufficient power in the already degraded light near the limb to depict the yet more degraded dusky spot.

The Annular Eclipse of the Sun 1894 *April* 6.

By C. Michie Smith.

The first contact was lost through clouds, but the last contact was well observed, as follows :—

	M.M.T. h m s
Prof. R. Ll. Jones	21 17 43·8
C. Michie Smith	21 17 42·3
K. V. Sivaramiah	21 17 43·4

A number of photographs were taken during the eclipse with the hope of obtaining signs of the Moon against the corona, but without definite success. The eclipse was not annular at Madras ; but as the magnitude of the eclipse was 0·96, the reduction in light was very marked and the meteorological effects were considerable, as is shown by the following table :—

Meteorological Observations at the Madras Observatory 1894 *April* 6.

h	m	Reduced Barom.	Thermometer in Shade. Dry.	Thermometer in Shade. Wet.	Humidity.	Sun. Maximum Thermometer.	Remarks.
19	0	29·926	76·9	75·1	92	...	
19	15	...	78·1	75·8	90	...	
19	30	...	79·1	76·2	87	...	Dew began to be deposited about 19h 30m and continued for nearly an hour.
19	45	29·947	79·8	76·8	87	82·1*	* In the shed.
20	0	·957	79·0	76·6	89	86·5	
20	15	·960	79·0	76·8	90	86·8	
20	30	·961	80·4	77·4	87	96·5	
20	45	·962	81·9	77·8	83	109·8	
21	0	·969	81·8	77·5	82	115·3	
21	15	·973	83·5	78·8	80	120·5	
21	30	·971	84·4	78·8	77	128·3	

The normal rise of the barometer between 7 A.M. and 9 A.M. at this season is 0·028 in. Many of the observers who have to telegraph to Simla the weather observations at 8 A.M. used the code word for "dark gloomy weather"!

A number of photographs taken by amateurs throughout the presidency, including one of the annular phase taken at Cuddapah, were forwarded to the Observatory, but none of them contained any features of special interest.

The Solar Eclipse of 1894 *September* 29.

The following observations were obtained :—

Observer	First contact. M.M.T. h	m	s	Last contact. M.M.T. h	m	s
C. Michie Smith	21	3	27·6	22	29	29
K. V. Sivaramiah	...			22	29	2·3

Madras Observatory:
1894 *October* 25.

Total Eclipse of the Sun, 1894 September 29.

Extract from the Meteorological Log (9,399) *kept on board the SS. "Yarrawonga."* By Captain H. G. Thomas.

(*Communicated by the Secretaries.*)

This eclipse was looked for on the morning of the 29th, but we were unable for clouds to note the time of first contact. As we were to the northward of the line of central shadow, it was observed by us as a partial eclipse. The central phase took place at 9.20 A.M., corresponding to G.M.T. $28^d\ 16^h\ 31^m\ 42^s$, the Sun's diameter being about $\frac{3}{4}$ hidden, disclosing a crescent at the underneath part. The sky keeping clear, the eclipse was observed to finish at 10.57 A.M., corresponding to G.M.T. $28^d\ 18^h\ 8^m\ 42^s$. Position of ship at central phase—Lat. 7° 17′ S., Long. 70° 12′ E. Position of ship at finish—Lat. 7° 6′ S., Long. 69° 58′ E.

Meteorological Office:
1894 *November* 8.

Observations of the Transit of Mercury on 1894 November 10 at Sidmouth, Devon. By A. F. Lindemann.

1. The observations were made on Muttersmoor, about 630 feet above sea, near Sidmouth, in N.L. 50° 41′ 28″ and W.L. 3° 16′ 2″, by Professor H. H. Turner, of Oxford, and A. F. Lindemann, of Sidmouth.

2. *Instruments.*—Professor Turner : Refractor by W. Wray, aperture 3·04 inches, focal length 40 inches, magnifying power 155, measured by observations on a graduated staff at noon, November 11. Eye-piece pulled out and image thrown on card screen firmly attached to telescope by wooden bars, so as to give an image of the Sun 3 inches in diameter. (It was intended to have this image 6 inches in diameter, but in the hurry of putting up the instrument after the shower mentioned below the wooden bars were attached too far up the telescope tube, and could not be altered in time. A black cloth was used to shut out stray light, and the observations were found very easy.)

A. F. Lindemann : Refractor by T. Cooke & Sons, 2·44 inches free aperture, 37 inches focal length. Eye-piece magnifying power 55, similarly determined on November 11.

3. *Watches.*—The pocket watches of the party were used and were compared as follows, being denoted by the following initials :—

(1) Miss Dora Davidson's watch, D.D.
(2) Professor Turner's watch, H.T.
(3) A. F. Lindemann's watch, L.

D.D. h m s	H.T. h m s	D.D.—H.T. s	Date.
3 21 0	3 20 53·8	+ 6·2	Nov. 10
5 11 20	5 11 15	+ 5·0	10
10 56 30	10 56 28	+ 2·0	10
4 52 30	4 53 1·5	−31·5	11

L. h m s	H.T. h m s	L.—H.T. m s	Date.
3 22 0 p.m.	3 20 10	+1 50	Nov. 10
4 32 30	4 30 38	+1 52	10
5 43 0	5 41 6·7	+1 53·3	10
10 40 0	10 37 51·7	+2 8·3	10
4 36 30	4 34 16·8	+2 13·2	11

4. Comparison with Sidereal Clock (T. Cooke & Sons) at Sidholme Observatory :—

	h m s	h m s	
H.T. =	5 38 43·7	= 20 54 0·0	Cooke
L. =	5 42 37·0	= 20 56 0·0	„

5. *Error of Sidereal Clock.*—Three stars (*α Cephei*, *β Aquarii* and *ε Pegasi*, one N. and two S. of the zenith) were observed with the Sidholme transit, and gave a clock error of $7^m\ 23^s{\cdot}0$ (fast) at $21^h\ 30^m$ sidereal on November 10. From further observations on November $12^d\ 1^h$ (sid.) the clock was found to be $7^m\ 51^s{\cdot}2$ fast, giving a rate of $0^s{\cdot}57$ per hour gaining.

6. *Error of Watches on* G.M.T.—From the above comparisons and observations the errors and rates of the watches at the time of observation were found to be—

	m s	s
D.D.	1 18·2 slow, losing	0·21 per hour.
H.T.	1 23·7 „ „	0·07 „
L.	0 28·6 fast, gaining	0·57 „

7. *Observations of Ingress.*—Arrived at observing-station at $2^h\ 42^m$ G.M.T., $2^h\ 52^m$ quite overcast, $3^h\ 8^m$ raining hard, but clearing in W. The party sheltered in the carriage and compared watches as in §3. About $3^h\ 30^m$ cleared up and instruments quickly erected; all ready and quite clear at $3^h\ 49^m$.

Professor Turner's observation by watch D.D. (time taken by Miss Dora Davidson) :—

	h m s		h m s
D.D.	3 55 0	"slight cloud."	G.M.T. = 3 56 18·2
	3 55 30	"Mercury suspected."	3 56 48·2
	3 56 44·5	"first thread of light."	3 58 2·7

10 seconds later well separated.

A. F. Lindemann observed internal contact by

	h	m	s
L.'s watch at	3	58	15
Watch error			−28·6
G.M.T. =	3	57	46·4

15 seconds later separation quite distinct; $4^h\ 10^m$ G.M.T. quite cloudy.

The white spot was not seen, although looked for directly, without success, by both observers.

On the late Transit of Mercury. By the Rev. S. J. Johnson, M.A.

November 10 was mild here, with frequent showers, one of which ended too slowly at the time of ingress, when the Sun came out at $3^h\ 58^m\ 12^s$. The internal contact of *Mercury* with the Sun seemed to have taken place hardly more than 5 seconds. This would be later than the predicted time by about $\frac{3}{4}$ minute. The disc of the planet was jet black. It seemed to resemble a shot on a bright background. No halo was perceptible, though it was carefully looked for. By way of trial, I took some micrometer measurements of diameter, the mean of which came out 8″·8; quite as near as could be expected, considering the Sun's limb was boiling and the planet very tremulous. The transit was visible for exactly twenty minutes, when the Sun disappeared behind a small black cloud. No power higher than 50 on a 3½-inch telescope could be employed.

Melplash Vicarage, Bridport:
December 8.

Observations of the Transit of Mercury, 1894 *November* 10, *made at Grahamstown, Cape of Good Hope.* By L. A. Eddie.

The sky was clear in the vicinity of the Sun as the moment approached for external contact at ingress, though there were many light clouds in the east, and lateral strata of fine cirri clouds lying on the western horizon and extending to a little below the position of the Sun. The air was warm and calm, but a low barometer bespoke that a change was at hand, which was already indicated by an unsteady condition of the atmosphere around the Sun's periphery, causing a constant succession of rapid undulations, which I feared would intercept the detection of external contact. There were seven conspicuous sun-spots on the solar disc, in three groups of two spots each and one single one just within the western border. The instrument used was a 3-inch refractor, powers 32 and 120.

Notwithstanding the scollops around the Sun's disc, I was fortunate enough to detect, as near as possible, the very earliest contact of *Mercury* with the Sun's limb at the exact point where I was expecting it, having selected this point as being about the required 98° from the north. I suddenly caught the faintest enlargement, as it were, of one of the undulations, and called to my assistant with the timepiece, who recorded $5^h\ 25^m\ 38^s$. It was impossible to bisect the planet with any degree of accuracy, owing to the atmospheric undulations encroaching upon this tiny disc and diminishing it. I was therefore a little late with this estimation, which was recorded at $5^h\ 26^m\ 58^s$. The estimated time of internal contact was also retarded, the planet seeming to adhere to the periphery of the Sun, though no black drop phenomenon was apparent, the unsteady atmosphere, resulting in the agitation of the Sun's limb, alone seeming to prevent the earlier detection of the completion of the planetary circle, and thus causing a lagging at internal contact. The time recorded for this event was $5^h\ 27^m\ 38^s$; but as soon as the planet had fully freed itself from contact, I could perceive that it should have been recorded some seconds earlier.

I could not trace the remainder of the planet's disc outside the Sun's limb after it had begun to enter upon his face, as I was able to do with *Venus* during transit in 1882; but this might have been owing to the smallness of *Mercury* and the unsteady definition. When fully on, the planet appeared to be surrounded by a dusky ring of grey light, in depth about one-third of the diameter of the planet itself, and somewhat less brilliant than the general solar surface.

No bright spots were detected within the planet's disc, but the latter appeared to me at times to be of a deep chocolate brown rather than black.

When the Sun had descended behind the bank of cirri clouds it closely resembled *Jupiter*, the transparent clouds forming the belts, and the planet *Mercury* a satellite in transit.

The Sun set at $6^h\ 8^m$, Cape uniform time, about 43 minutes after *Mercury* had entered his disc; the planet had then advanced about one-seventh of the chord to be travelled across the face of the Sun.

Grahamstown, longitude 26° 31′ 18″ E.; latitude 33° 19′ 7″ S.

	Cape uniform time. d h m s	Aperture. inches.	Power.
External contact	10 5 25 38	3	32
Planet bisected	10 5 26 58	3	32
Internal contact	10 5 27 38	3	32

Grahamstown:
1894 *November* 12.

Observations of the Transit of Mercury on 1894 *November* 10.

By Lieutenant Basil Taylor, R.N.

(*Communicated by the Secretaries.*)

The first external contact is very approximate, as I did not know exactly the point of the Sun's limb to watch.

The first internal contact is timed as accurately as possible, but may be slightly too early through my inexperience in observation.

I was unable to see the Sun at the time of egress, as it was obscured by heavy clouds.

The instrument employed was a 2·25-inch refractor with power of 80; the telescope mounted on a tripod. The times were taken with two watches, which were compared shortly before with three chronometers on board this ship: the comparisons are given below.

Comparisons were also taken of the same chronometers after the observations, which gave the same errors.

Place of observation: Lat. 32° 19′ 10″ N., Long. 64°49′15″ W.

	Times by (i)	Times by (ii)
	h m s	h m s
External contact at Ingress	23 36 30	(?)
Internal contact at Ingress	23 37 35	23 38 7

	h	m	s	
Error of (i) on G.M.T.	4	19	34·5	slow.
Error of (ii) on G.M.T.	4	19	1·5	slow.

Comparisons of watches (i) *and* (ii) *with Chronometers* A, B, *and* D.

	h	m	s		h	m	s
A.	2	26	0	A.	2	26	30
(i).	9	36	26	(ii).	9	37	29·5
Error of A. on G.M.T.	0h	29m	59s	fast.			
	h	m	s		h	m	s
B.	12	35	0	B.	12	35	30
(i).	9	37	41	(ii).	9	38	44
Error of B. on G.M.T.	1h	22m	15s	slow.			
	h	m	s		h	m	s
D.	3	30	30	D.	3	31	0
(i).	9	40	13	(ii).	9	41	17
Error of D. on G.M.T.	1h	30m	41s	fast.			

The errors of the chronometers were ascertained by observations of the Sun with sextant and artificial horizon on various dates during the month of October.

H.M.S. "Blake," North American Station:
1894 *November* 11.

Result of Micrometer-comparisons of Uranus and α Libræ, 1894 October 5. By John Tebbutt.

In consequence of cloudy weather, no other observations than those now sent could be secured near the conjunction of the planet and star. The 8-inch equatorial refractor with its excellent filar micrometer and lowest power, 74, was employed, one revolution of the adopted screw being 17″·869. Twenty comparisons were obtained in the evening twilight on the single transit thread of the micrometer, with the corresponding number of bisections of the star and planet for declination. As the limbs of the planet, though steady, were not well defined, the centre of the disc was observed for both right ascension and declination. The following are the results, the apparent place of the star being taken from page 353 of the *Nautical Almanac*, and that of the planet being interpolated with third differences from page 267 of the same work. The corrections for refraction are insensible.

	R.A.			Declin.		
	h	m	s	°	′	″
Apparent place of Star	14	45	1·97	−15	36	16·8
Observed difference of Planet and Star ...			+6·28			−13·4
Correction for Parallax			+0·02			− 0·2
Concluded Geoc. App. place of Planet's Centre	14	45	8·27	−15	36	30·4
Geoc. App. place from *Nautical Almanac* ...	14	45	8·59	−15	36	31·6
Correction for *Nautical Almanac*			−0·32			+1·2

The Windsor mean time corresponding to the concluded position is October $5^d\ 6^h\ 22^m\ 13^s$.

Windsor, N.S. Wales:
1894 *October* 13.

Observation of a Daylight Occultation of Antares, 1894 October 31. By John Tebbutt.

The circumstances of this rare phenomenon were kindly calculated for my observatory by Mr. R. T. A. Innes, of Sydney, and Mr. Joseph Brooks, the officer in charge of the trigonometrical survey of the colony. The evening turned out beautifully clear, and excellent observations were obtained of the phenomenon by means of the Cooke filar micrometer and a power of 138 on the Grubb 8-inch equatorial. The telescope was first turned on the star about an hour before the calculated time of disappearance at the Moon's dark limb, but the image was badly defined and flaring. The steadiness and definition, however, wonderfully improved as the afternoon advanced, and at the time of the first

phase were satisfactory. Shortly before the disappearance the star was brought midway between the position threads of the micrometer, which were, of course, set parallel to the equator. The star was observed to disappear instantaneously between the threads at $20^h\ 12^m\ 23^s{\cdot}0$ per sidereal chronometer corrected, the corresponding local mean time being $5^h\ 34^m\ 1^s{\cdot}4$. As the Sun's upper limb was observed to disappear on the visible horizon at $6^h\ 20^m\ 29^s$ it follows that the first phase was observed $46\frac{1}{2}$ minutes before direct sunlight ceased. The telescope was kept clamped in declination in order that the position threads of the micrometer might serve to point out approximately the place where the star would reappear on the bright limb. By allowing a little for the change of refraction in the interval, I fortunately had my eye directed to the exact place of reappearance. The irradiation of the crescent limb was much reduced by the strong twilight, and the star was caught at $21^h\ 21^m\ 13^s{\cdot}8$ (per sidereal chronometer corrected) as a small round white disc, which gradually became brighter as its distance from the limb increased, and in a minute or so shone out with its usual ruddy glare. Nothing was seen of the well-known companion. Considering the strong twilight and the high power employed, it was hardly possible to distinguish it. The deduced mean time of reappearance is $6^h\ 42^m\ 40^s{\cdot}9$. As both phases were well observed, and the occultation was nearly central, the observations will afford an accurate place of the Moon when the longitude of the observatory is definitively settled. On reviewing an experience of thirty years of occultation work, I find that I had previously observed four occultations of *Antares* and one of *Spica* on a dark sky, but that I had never before observed an occultation of a fixed star in full sunlight. I conclude, therefore, that the observation just recorded is a rare one. I may add that according to Mr. Brooks's calculation *Spica* will be occulted soon after noon on the 24th instant, and *Antares* will again be occulted shortly after sunrise on December 25, civil time. I may also add that I will do my best to observe these important phenomena.

Private Observatory, The Peninsula, Windsor, N.S. Wales:
1894 *November* 3.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. JANUARY 11, 1895. No. 3

Captain W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

John James Aubertin, 33 Duke Street, St. James's, S.W.;
Charles Josephus Green, M.R.C.S., L.S.A., 10 St. Paul's Square, Preston, Lancashire;
Frederic Hammond, F.R.I.B.A., 2 Mercer's Road, Tufnell Park, N.;
William Harnett, Cullentra, Wimbledon Park, S.W.;
Rev. Thomas Roseby, M.A., LL.D., The Parsonage, Marrickville, Sydney, N.S. Wales, Australia;
Rev. Peter Hately Waddell, M.A., B.D, The Manse, Whitekirk, Prestonkirk, East Lothian, Scotland; and
Robert Wigglesworth, Esq., York, and 8 Victoria Street, S.W.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:

George Denton Hirst, Sydney, New South Wales, Australia (proposed by H. C. Russell);
Samuel V. Hoffman, 1 Chelsea Square, New York City (proposed by Chas. Lane Poor);
Henry T. C. Knox, F.R.G.S., Lieutenant, late Royal Navy, 17 Upper Montagu Street, W. (proposed by G. F. Chambers);
E. F. J. Love, M.A. (Cantab.), Lecturer on Physics at the University, Melbourne, Victoria, Australia (proposed by R. L. J. Ellery); and
Rev. Daniel Higham Sparling, B.A., Biddulph Moor Rectory, Congleton (proposed by T. K. Mellor).

Seventy-four presents were announced as having been received since the last meeting, including amongst others:

Astronomische Gesellschaft, Catalog, vi. Zone +40° bis +50° (Bonn), presented by the Society; J. E. Gore, The Worlds of Space, and J. R. Hind, Illustrated London Astronomy, presented by Mr. M. C. Sharp; *Nautical Almanac* for 1898, and ditto, Part I., presented by the Lords Commissioners of the Admiralty; photograph of *Orion*, &c., made with a small camera, presented by Dr. Sheldon; a series of eight untouched enlargements of portions of the Moon, from a negative by Lœwy and Puiseux, made and presented by Professor L. Weinek.

Preliminary Note on a Modified (Oblique) form of Cassegrain Telescope. By A. A. Common, LL.D., F.R.S.

Reflecting telescopes on the Cassegrain system, but with the convex mirror placed so as not to obstruct the light from the object, and with the mirrors tilted so as to throw the image to one side of the large mirror, appear to have been made in Germany many years ago.

I first learnt this from Dr. Hugo Schroeder in the course of a conversation about the possible forms of the reflecting telescope. This was, I think, before I began the present 5-foot telescope in 1886. He suggested that I should make it on this principle, and I made some experiments with small mirrors, but, as far as I remember, I did not get better definition than the Herschelian form would give. More than one eminent authority on the theoretical side assured me that good definition was not possible on this plan, and I did not then pursue the experiments further. In 1892 I found it so difficult to properly fix a spectroscope to the 5-foot, and to manipulate it from the stage, and the danger of getting up and down from a high stage in the dark becoming rather pronounced, I determined to seek some more convenient form of telescope.

As I had a 5-foot mirror with a hole in the centre, I could use the Cassegrain form, but before doing so I decided to try again the oblique form, as this allowed high altitudes with my form of mounting. From my previous trials, and from what I had heard from others of the possible definition, I was led only to expect perhaps enough for spectroscopic work.

The results of my experiments, however, have been, in my opinion, so thoroughly satisfactory, that I think it right to lay them before the Society.

Having nothing to go upon except the fact mentioned by Dr. Schroeder, that small telescopes on this plan had been made, and not being able to attack the problem from the theoretical side, I had to do so from the experimental or practical side. I began by trying the effect of a convex mirror on the obliquely

reflected rays from a 20-inch mirror of short focus length (so that the adverse conditions would be intensified), using an illuminated pinhole at the centre of curvature. Experiment showed that at certain angles the astigmatism of the image from the concave mirror could be almost entirely eliminated by the opposite astigmatism of the convex; this was very evident when extreme angles of obliquity were used. This compensating principle, once established, gave great hopes of success.

A mounting was erected to carry a 6-inch or 12-inch concave speculum, with provision for using various convex mirrors, and experiments made to find the combination of curves and angles that would give the best definition on stars. Many experiments were made with more or less success, and a great deal of time was lost through bad weather. Combinations that gave excellent results on the Sun failed to give a perfectly round image of a star. With mirrors smaller than 6 inches a very fine stellar image was obtained on more than one occasion. This trial telescope was given up in favour of an artificial star in the workshop and a paralle' beam from a 6-inch achromatic; this allowed the carrying on of the experiments continuously.

Hitherto the angle of reflection from the small mirror had been kept the same as that from the large one, but it was soon found that to get proper definition the angle of the second reflection had to be considerably larger than the first.

The conditions that seemed to answer best, and which gave, as far as could be seen with this arrangement, perfect definition, were, a focal length of the concave mirror of 10, aperture being 1, a radius of curvature for the convex mirror $\frac{3}{4}$ of concave, and distance from concave $\frac{2}{3}$ of focal length; the angle between first central incident and reflected ray being 5° 30′, and between the second 12° 30′.

With these conditions it was decided to try this form of telescope on a large scale, using as much of the 5-foot mirror as the focal length would allow under these conditions (about 32 inches); the flat mounting of the 5-foot was cleared away, an 18-inch tube about 20 feet long was fitted to the main tube, with an eye-end and arrangement for carrying a convex mirror with adjustments. Two 15-inch convex mirrors were made to the proper curvature. With this arrangement the stars were not perfectly round—in fact they all had tails, and in appearance were very like comets with short tails. Definition was fairly good on the Moon, as photographs taken with this telescope which are laid before the Society show. They are almost, if not quite, as good as any I have hitherto obtained.

The defect in the image of a star was considered to be due to the fact that owing to the shape of the square tube of the 5 foot and the want of sufficient play to move the mirror, an eccentric portion had to be used. This difficulty could not be overcome, so it was decided to make a 30-inch mirror of the same focal length and fit it in the cell of the C speculum, which was in

the workshop. This mirror was made and silvered, and the C speculum taken out of its cell and this mirror put in, eccentrically as regarded the cell, but in the proper position as regarded the position of the convex mirror and the possible place of image. The B mirror was taken out of the telescope and the 30-inch mirror and cell put in its place. This was completed a few days before last Christmas, and the first opportunity taken of examining a star ; when it was found that, as far as could be seen on that night, which was not very good, the stars were round, and free from any kind of appendage. Inside and outside the focus the discs were quite circular. Observations since made show that with a power of 1100 the image of the star is not quite round, with lower powers it seems so. This slight defect, I consider, may be due to a slight want of adjustment.

On the Moon the definition was very fine indeed, finer than anything I have yet seen. *Jupiter* was very finely seen in a quite dark field. This was a striking contrast to the usual field with the 5-foot when such a bright object as *Jupiter* was under examination.

The advantages of this form of reflecting telescope are many and important, particularly so in the case of very large telescopes. The greatest gain is, perhaps, in the change of position of the image, so that a low stage near the centre of motion of the telescope and the ground level, will take the place of the high stage with its continuous shifting to suit the height of the end of the telescope and the motion in time.

The increase of focal length is a gain both for visual and spectroscopic work ; it may not be so good for nebular photography, but it is quite an open question whether the larger primary image is not at any time worth the greater time in exposure required, and plates are improving so rapidly that this will not be felt. (Using the 5-foot aperture some years ago, I gave quarter of a second exposure to the Moon. In November last I took a picture of the Moon with a convex mirror, giving an equivalent focal length of about 80 feet and an image $8\frac{1}{2}$ inches in diameter. Using only one foot aperture and two seconds exposure, I obtained a picture with ample density.)

The place of the image being near the strongest part of the tube, any kind of apparatus can be rigidly attached and manipulated under the most variable circumstances.

The dark field to which I have alluded is a great advantage on such objects as *Hyperion*, and the absence of the cause of the diffraction lines (the supports of the small mirror of the Newtonian) will tell on photographs of stars.

There is hardly a defect under which the large reflector at present labours that this plan of telescope will not remove, whilst it brings in some distinct gains of its own—as, for instance, the substitution of a convex for a plane mirror, and the great shortening of length of tube for a given focal length. In this latter respect the gain can be very great, an equivalent focal

length of, say, 200 feet, requiring in the case of the Newtonian a tube nearly this length, can be obtained by a tube of about 66 feet. In no other way could such a large primary image as a focal length of 200 feet would give be obtained, while retaining, say, 1° of the field. The image of the Moon would here be about 22 inches in diameter, with the above relation of curvature of surfaces, but this relation need not necessarily be adhered to, where, for the Sun or Moon, the aperture might be very much less than in the proportion given, as an increase in the curvature of the convex mirror produces a longer equivalent focal length; and as this can be done more easily as the aperture of the concave mirror is reduced, and the first angle made smaller, a much greater equivalent focal length could be obtained; and as I have shown, one foot of aperture is sufficient to give an image of the Moon when the equivalent focal length is 80 feet, a mirror of, say, 2 feet aperture and a slightly longer exposure, mounted on any of the very large refractors in existence, would easily give a much larger primary image—too large, perhaps, to photograph as a whole, but excellent for portions of such an object as the Moon.

The conditions I have given may not be the best to get the finest definition: probably they are not. It is easy to see that where there is a balancing process at work between the two mirrors, the angles of incidence and the place where the image is produced have an importance, as well as the curves of the mirrors. With a parabolic mirror and a spherical convex, the image is as it would be in the Cassegrain form, with these mirrors over-corrected. Whether it would be an advantage to reduce the amount of correction given to the concave mirror, to make it as if the focal length were to be the equivalent focal length; or whether it would be better to obtain this correction, as in the Cassegrain, by making the convex curve an hyperboloid, is yet to be seen. I am working at this, and hope to have something from trial; but, in view of the possibilities of this form of telescope, I hope that some competent person will take up the investigation of the theoretical conditions involved, so that the best can be made of this form of reflecting telescope.

Preliminary Note on the Determination of Terrestrial Longitudes by Photography. By Captain E. H. Hills, R.E.

The question of the practicability of some method for the determination of longitudes by means of photographs of the moon and stars is one that has engaged the attention of several experimenters.

It is one of great importance for the explorer and surveyor, the inaccuracy of the methods at present available being so great that they are practically never employed in the field.

Among others Dr. Schlichter, in England, and Dr. Runge, in Germany, have worked at this subject. The latter attempted no great degree of accuracy, but directed his attention rather to the question of the possibility of obtaining a rough approximation by the use of an ordinary photographic camera and watch, than to the investigation of the maximum accuracy obtainable by using a suitable instrument. At the same time Dr. Runge was, I believe, the first to suggest that it was not at all necessary that the Moon and star exposures should be made at the same time. This, as will be seen, is an integral part of the method now brought before the Society.

Dr. Schlichter worked on the method of photographing the Moon and a bright star near it, and measuring the lunar distance on the plate. There seems no doubt that results can be obtained by this method far exceeding in accuracy any that can be obtained by the use of a sextant or theodolite. The principal objection to its general use seems to lie in the fact, that there would be very few nights in the year when it could be employed, unless the photographic plate were made to include a large angle, which would be undesirable for many reasons. It is also an objection to this method that the measurement of the angular distance between Moon and star involves a knowledge of the focal length of the lens, and that change of temperature would affect the result in a degree by no means negligible.

The present method is available any night that the Moon is visible, and the reductions involve a knowledge only of the approximate position of the optical centre of the plate, which change of focal length will not affect. It is as follows:

The camera is set up so that the image of the Moon is about the centre of the plate and a series of instantaneous exposures are made, allowing such an interval between the exposures that the Moon images on the plate will not overlap, *i.e.* from $1\frac{1}{2}$ minutes to $2\frac{1}{2}$ minutes according to the Moon's age.

After a set of, say seven, Moon exposures the camera is left untouched until bright stars of approximately the same declination as the Moon have arrived at the same point in the heavens. The camera is then opened for periods of one minute and the stars allowed to impress their trails on the plate. These star exposures would be repeated four or five times. It is immaterial whether the star or the Moon exposures be made first, and if found convenient two sets of star exposures may be made in order to get stars on both sides of the Moons.

It is obvious that if the L.M.T. of the Moon and star exposures be known such a plate gives all the data necessary for computing the Moon's R.A. at the time of each exposure, and hence the G.M.T. and longitude.

The camera employed was one specially designed for this work. It was made regardless of weight, and is somewhat heavy (55 lbs. including stand). This weight might, if thought advisable, be considerably reduced in a future pattern.

The only two essentials are:

(1) Stability. A camera of this size, 19½ inches focal length, in combination with a suitable micrometer, may be looked upon as an instrument reading to seconds of arc, and will require the same degree of stability. There is, however, this in favour of the camera, that it need not be touched from the first exposure to the last one, and the observer may remain at a distance of several feet from it, the exposures being made by a pneumatic shutter actuated by an india-rubber ball and tube; and this shutter may be placed on a separate stand.

(2) Means of adjusting the plate at right angles to the optical axis.

This is the only instrumental adjustment required, and is done as follows:—The sensitive plate in the dark slide is pressed up against three sharp-pointed screws, which puncture the gelatine film, and leave three points from which the position of the plate in the slide can be determined. To adjust and find the "centre" of the plate the camera is placed lens downward over a mercury bath, and a piece of plate glass placed in the position of the sensitive plate and levelled. Then that point on the plate which coincides with its reflected image is the point at which a perpendicular from the centre of the lens cuts the plate. The position of this point with reference to the points of the three screws being once found, it can be marked on the sensitive plate after exposure and development.

The lens used with this camera was a Dallmeyer Rapid Rectilinear, of 19½ inches focal length.

The measurements were done with a micrometer reading to ·001 mm.

Two axes approximately at right angles, and approximately parallel and perpendicular to the meridian through the centre, were ruled on the plate with a needle, and the coordinates measured from these. The semidiameter of the Moon images was measured on the plate, so that coordinates of the Moon's centre were obtained.

The method employed for reducing the measurements is that worked out by Professor H. H. Turner for reducing the Astrographic Chart plates. (See *Monthly Notices, R.A.S.*, November 1893.) The R.A. and N.P.D. of the centre can be found by any approximate method; it will suffice if they are correct within a few minutes of arc.

No small part of the success of this as a practical, working method of longitude determination is due to these elegant and convenient formulæ, without the aid of which the computation of a plate would be most laborious.

The two plates, of which the results are given below, were exposed at the Royal Engineer Observatory, Chatham, on the

night of 1894 October 16. In these first experiments the camera was placed on a solid masonry pier. In each case seven Moon exposures were made, and *Jupiter* and *Aldebaran* were used as reference stars. The times were taken with the Observatory clock, transits being taken as opportunity offered.

Any error in time will produce the same error in the resulting longitude, but it is evident that any error in the assumed clock rate will, by affecting the scale of R.A. on the plate, produce a similar error in the Moon's R.A., and hence a large error in the longitude.

The following tables show the longitude as worked from these two plates :

	Plate 1. Longitude. m	s		Plate 2. Longitude. m	s
Moon 1	1	59·4	Moon 1	2	4·2
2	2	4·8	2	2	8·3
3	2	3·5	3	2	8·1
4	2	12·7	4	2	12·0
5	2	13·1	5	2	6·1
6	2	7·8	6	2	7·8
7	2	8·2	7	2	6·7
Mean	2	7·07	Mean	2	7·60

The true longitude was $2^m 8^s \cdot 13$, and the errors of these two determinations were, therefore, $1^s \cdot 06$ and $0^s \cdot 53$ respectively.

The principal source of error that this method is liable to, is the difference in refraction, owing to the different states of the atmosphere at the times of the Moon and star exposures. This error will disappear if the photograph be taken on or near the meridian, because in that case a change in apparent altitude will not affect the Moon's R.A. as measured from the plate. It is noteworthy that of the two plates, given above, No. 2 was exposed on the meridian, whereas in the case of No. 1 the Moon was some three hours from the meridian. It may be only an accidental coincidence that the result of No. 2 has only half the error of that of No. 1, but there is no doubt that the conditions for maximum accuracy are to expose near the meridian, unless there are stars in such a favourable position that only a short interval is necessary between the two sets of exposures.

It is, of course, essential that more plates should be exposed in order to gain further experience of the method, but it seems reasonable to suppose that this will result in increased accuracy being obtained, and even as the results stand now they are many times more accurate than could be obtained by any other method with a portable instrument.

Note.—The condition given above as regards exposure on the meridian being essential for obtaining the maximum accuracy is

only correct if the Moon's R.A. is used in finding the longitude, as was the case with the plates of which the results are given above. Professor Turner has pointed out that if the Moon's place be left in standard coordinates, and not converted into R.A., it is possible so to select the coordinate axes that the refraction error would be eliminated in all cases.

Notes on Suitable Stations in Norway for Viewing the Total Eclipse of the Sun on 1896 *August* 8. By Colonel A. Burton-Brown, R.A., F.G.S.

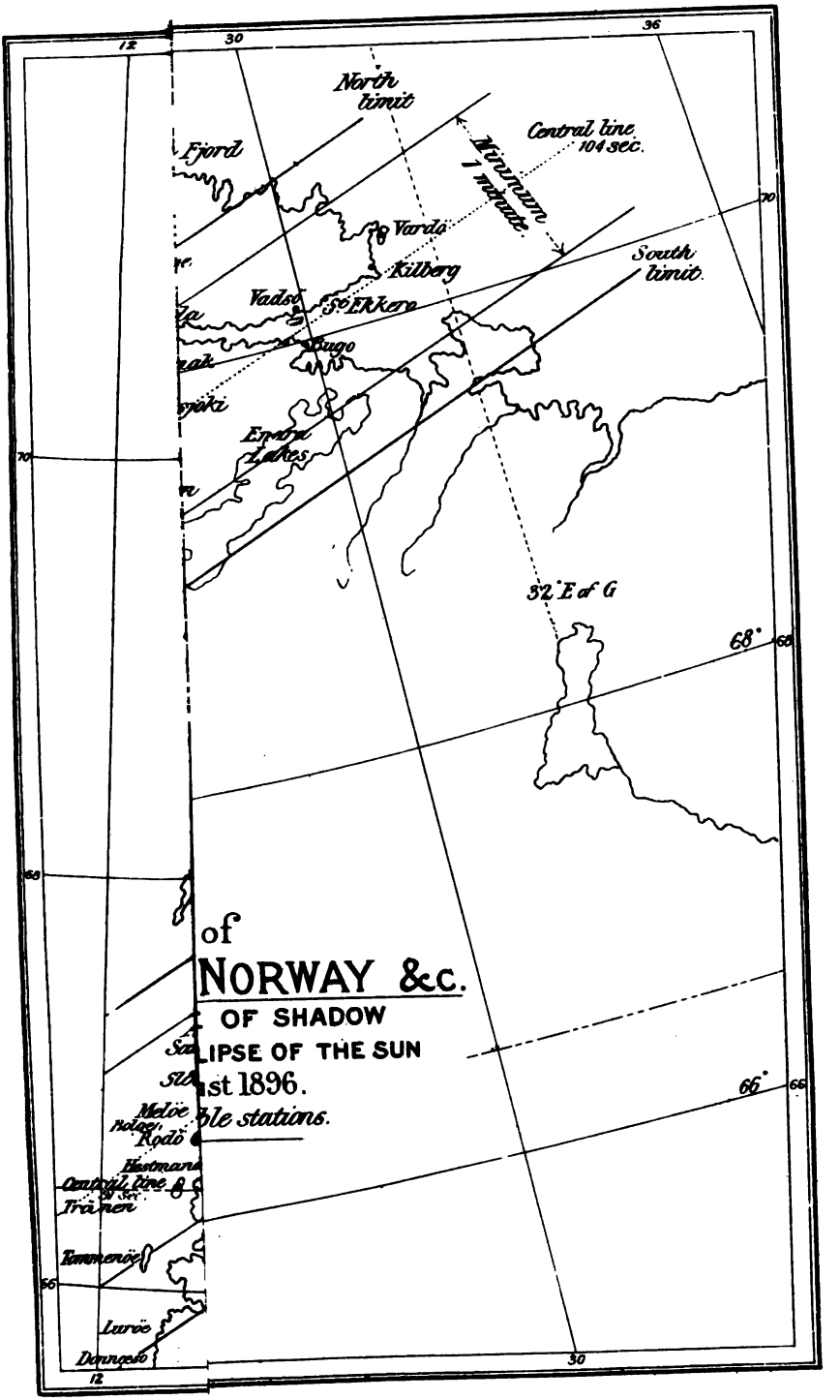
It having come to my knowledge that some doubts had arisen as to the suitability of Norway as a post of observation for the total eclipse of the Sun in 1896, and having had both experience in total eclipse expeditions and of travelling in Norway, I thought I could not do better than spend my summer holiday in obtaining information that might be useful to Fellows of this Society and astronomers generally. Accordingly, I determined to make a special tour of observation both to the west coast, and also to Finmarken, Lapland, and the Russian frontier on the east coast. It was clear to me that some notes that had been published on the subject entered somewhat into the region of speculation, and might possibly in such an exceptional country as Norway, broken up into mountains and fjords, and where it was difficult to get trustworthy maps or guides, result in disappointment. Having, therefore, arranged to spend some weeks on this work, I started early in June for Trondhjem and the North, and have now the pleasure of laying before the Society the result of my observations. Since my return, in order to compile a suitable map to illustrate this paper, I wished to verify certain astronomical work, and I desire to express my thanks to Professor Turner and to Mr. A. C. D Crommelin for useful notes and calculations, and in a very large measure to Captain Wesfel, of the Norwegian Artillery, who accompanied me in my journey through Finmarken, and whose knowledge of Lappish and Russian enabled me to penetrate far up the Tana River and other out-of-the-way parts amongst the Finns. My own knowledge of the languages, and of Laplanders' and Norwegian manners and customs, also stood me in good stead. I had previously found that on travelling out of the beaten track very little dependence can be placed on guide-books—even the usually reliable Baedeker is full of errors—and this made me more anxious that astronomers taking part in this expedition, especially as some of the posts would be found in isolated and more or less un-get-at-able spots and difficult of communication, should not be led astray in this matter. Statements having approximate truth may be good enough for ordinary tourists, but yet utterly insufficient for the careful work of an observer of an eclipse expedition.

It appeared to me that in selecting stations in such an exceptional country as Norway, many points must be considered that do not apply to most places; thus it is not enough to know that A is twenty miles from B without also knowing how many fjords lie between, how many peaks three or four thousand feet in height, how many glaciers, and how far they are crevassed, if the mountains are passable, and if so what weight besides himself a man can carry up. Those people who have visited Norway, and the more so those who have travelled in the interior and north of the country are surprised at the almost impossibility of moving at all except by the fjords and certain made roads. These generally may be said to extend as far north as Trondhjem, lat. 63°26′; long. 10° 30′ about. After that, on the north and north-east coast and Russian frontier, roads are the feeblest tracks generally, and the fjord communication only of a special character; the population, except at such places as Tromso, Hammerfest, Vardo, and Vadso, is very scanty, and chiefly confined to the sea coast, and in the latter case subject to considerable variation, according to the season of the year and the nature of the fishing. How far these points would affect an astronomical expedition will be seen later on. It became necessary to divide my tour of observations into two parts: first, the easy part, on the west coast, the less valuable from an astronomical point of view, but which should not be disregarded, and which we may call the pleasure trip; and second, the difficult but more valuable part, on the N.E. of Norway.

Leaving Trondhjem, we take a N.N.E. course, passing Torghatten, an island of about 800 feet in height, and shortly after pass the Island of Donnæso, at the bottom of the map‡ on the west side, where we should be on the border of the shadow during totality; steaming north to Tommen Öe, which will have about one minute totality, a careful search for stations is kept. Lüröe is too low, Oxtinden Promontory too much inland. We reach Hestmandöe,* well within the 85 sec. line, and the Island of Tränen, near the 12th parallel, too far west, though the central line passes close by; but having a longitude of only 12° 5′, the Sun is rather low. Height of ground, 3710 feet. Röd Löven† also, somewhat further eastward, and Bolgen, a peaked island, close to the central line, but rather too far westward; passing Omnæs Öe and Melöe, crossing the central line, we next round the Promontory of Kunnen, two or three miles above the central line, a rather inaccessible position of some 2000 feet high. The lighthouse Island of Slöt is, however, in all respects a desirable position, and Kunnen has a telegraph station—a valuable adjunct. Proceeding E.N.E. we pass the Island of Fuglöe, 2300 feet high,

* To illustrate the inaccuracy of guide-books, one gives Hestmandöe, through which the Arctic Circle passes, as 66° 50′, another, 66° 20′; a question of importance to astronomers.

† Röd Löven marked Rodö on map. ‡ See Plate 2.


12
30
36
North limit
Central line 104 sec.
Fjord
Maximum duration
Varda
Kilberg
South limit.
Vadsö
Ekkerö
Hugo
Enare Lakes
70
32° E of G
68°
66°
66
Tränen
Tromsö
Lurö
Dønnesö
of
NORWAY &c.
OF SHADOW
IPSE OF THE SUN
st 1896.
ble stations.

steep and rugged, and 1½ miles further north Fleina, about 400 to 1000 feet—a good position. On the right is the Island of Sandhorn, with the Sandhornet Mountain of 3300 feet - a rare position for our mountaineers, only about five or six miles above the central line, with a minute and a half totality, and the Sun an altitude of 7½° about, the longitude being six or seven minutes over 14°. This position gives an uninterrupted view all round. For non-climbers the Arnöe Islands on west, where there are fishing stations, would afford an almost equally good position. These places are in easy communication with Bödo, whose lat. is 67° 17′, and long. 14° 24′ about, and which is ten miles direct north of the central line, where there is a hill to the N.E. of the town. Here excellent accommodation can be had, and a telegraph station exists. Further north is the Island of Lande Gode, within the 85 sec. limit. The Islands of Lundo and Engelo are on the northerly limit of the shadow of totality, and therefore useless. It seems to me that if Bödo was occupied as headquarters, with a steam launch at the disposal of the party, and Sandhornet, Arnöe, Fleina, Kunnen, or the lighthouse rock of Slöt, Bolgen, Röd Löven, or Hestmando as detached stations, a valuable area would be covered, although these positions have the astronomical disadvantage of the Sun's altitude being as low as $6\frac{5}{6}°$ to $7\frac{3}{4}°$, and the duration of totality but little over 1¼ to 1½ minutes. Yet, owing to the stillness of the atmosphere on the west coast of Norway at that time, and the general freedom from clouds on the horizon. some good results should be obtained. The further fact of the corona being seen through a considerable thickness of watery vapour would have both a spectroscopic and photographic interest *in comparison with similar observations taken at about double the altitude on the east coast.* The way to work this tour would be to take the ordinary Norse mail-boat from Newcastle to Trondhjem, *viâ* the Fjords, arriving at the end of July ; thence take the steamer to Bödo ; or if it is wished to extend the tour to the North Cape, a start of a week earlier must be made, and steamers changed at Hammerfest, or arrangements made to be disembarked at Bödo coming south ; or a steamer might be taken direct, slowly steaming over the central line and back. Although I have marked several islands in black on the map, my experience has shown some to be better adapted for many reasons than others. Thus Fuglöe is steep and rugged, and has no advantages over Fleina except height ; also Omnæs Öe is a troublesome place ; Kunnen is an almost inaccessible promontory of chert and granite rocks ; the Island of Slöt has a good anchorage for boats, and the Sun would not be masked by Kunnen during totality. Here also is a telegraph station.

Röd Löven and Omnæs have the disadvantage of being either east or south of those mentioned, and Bolgen, though well placed, would afford a steep and difficult climb. I have attached a map (see Plate 2) compiled from six or seven different English, French, Norwegian, Swedish, Russian, and other maps and charts,

reduced from the large scale one of 3½ inch to a mile [shown at the meeting], and I have entered on it the most suitable stations both on the east and west side of Norway. The shadow is shown as extending from 12° to 32° longitude east of Greenwich, and the line of 1ᵐ duration N. and S. of the central line (dotted) is also marked, the maximum totality on this central line increasing from 91ˢ to 104ˢ as we move eastward.

[The photographs handed round I must apologise for, as some are indifferent; but they will help, as will also the sketches, to illustrate and explain the paper.] I would now like to caution astronomers against guide-books, which are only suitable for casual travellers and those with ample time at their disposal; real information must be obtained from really good maps (difficult to get) and from people who have been on the spot and know what is required. Even that excellent guide "Baedeker" is more or less a fairy tale, and such astronomers who believe good accommodation is to be got at out-of-the-way places because a guide-book says so, may be sorely disappointed, as I have had the inconvenience of learning practically. Further, heights and distances from those sources must be received only as approximate. The writers of an interesting little paper suggest a station on the top of Sulitelma (see map and photo). As this would involve a special steamer up the Fjord from Bödo (or a still more difficult journey over lands and rivers), some eighty miles distant, several changes of conveyance, and four changes of boats to get to the bottom of the peak, then three or four days over glaciers and snow, on which journey all provisions would have to be carried, and even fuel and tents, part of the way, I cannot agree in thinking it neither dangerous nor very fatiguing, and I speak from mountaineering experience over 17000 feet high in the northern Himalayas. Norway is not open to tourists as Switzerland is, and before such an expedition is undertaken a course of mountaineering and arctic work should be undergone. Furthermore, no instruments of any size could be carried, and when once the peak is reached, the chances are ninety-nine out of a hundred that it would have its night-cap on, and no sun would be seen from it at all. This latter remark applies to all high mountains in Northern Norway, which have more or less snow on them, and are in the vicinity of glaciers. Thus the Bugönæsfjeld, for instance, near Vadso. If there is moderately high ground on islands such as I have mentioned, they are generally clear, but inland the reverse is the case. This year was quite an exceptional one, yet some of the photographs show clouds at or near the peaks. It may interest astronomers to hear that the "midnight sun" on July 9 in lat. 70° and long. about 18° 10′ was *perfectly* free from cloud. The temperature in its direct rays was 56° F., in the shade 52½° F. (or only 3½° F. diff.): its apparent altitude was about 5 diameters, and with a 2½″ object glass it would not burn paper, and only charred it in the focus of a 4″ glass, and the lines of moisture in the spectroscope were strongly marked. But to pass on: leaving

the west-coast positions, we reach Tromso, and steaming up to Hammerfest signs of civilisation die fitfully away. The coast is bleak and barren. On reaching Hammerfest we see the spot where a late President of the Royal Society, General Sir Edward Sabine, R.A., carried on his Pendulum Observations in 1823, and where a conference of astronomers of Norway, Sweden, and Russia on their labours from 1816 to 1852 fixed the northern termination of the 25° 21′ meridian from the Arctic Ocean to the River Danube. Here we probably change steamers and round the North Cape, 71° 10′ 40″ N., and about 26° E. ; steering east we pass the Nordkin, and from there in a S.E. direction along a bleak, inhospitable shore of quartzite rocks to Vardo, on an island, this is about the N.E. corner of Norway, a good sized whaling station, and a fort, with some second-class hotel accommodation. The high ground here would do for an encampment, or at least that portion not occupied with fishing lines and dried or, still worse, drying fish. This place was used as an observing station in 1769 by the Austrian Hell for the transit of Venus ; and, being less than twelve miles directly north of the central line of shadow, might be advantageously occupied. It forms the most easterly station ; being in long. 31° 8′, and lat. about 70° 22′, it would have a duration of totality of over $1^m\ 31^s$, and the Sun's altitude of about $14\frac{1}{2}°$. It is easily get-at-able, no high ground obstructs the view, and provisions and labour are to be had. Passing south down a dreary coast of quartzite rocks and Silurian slates, we come to Kilberg, about ten miles south, and two miles inland. There is a hill about 500 feet high, but although this would be only five or six miles north of the central line, it is not in other respects a desirable station. Steaming S.S.W. we pass Store Ekkero, a promontory some twenty-five or thirty miles west of Vadso, which appears to have all the attributes of a good station, provided accommodation can be arranged for : the central line of totality passes over the southern point, and there is a free view to the S.S.E. and E.N.E., the Sun's azimuth at the local time of 18^h being 97° south towards east, and the duration of totality a maximum—viz over $1^m\ 41^s$, the Sun's altitude about $14\frac{1}{4}°$. Passing on to Vadso, the town of the Finmarken district, there are several hills, two or three hundred feet, easily accessible, and in all respects suitable for observing stations within three or four miles ; indeed, Vadso should be looked upon as the headquarters of an East Norway expedition. The local time of totality here would be $17^h\ 57^m\ 46^s$, and duration about $1^m\ 35^s$. All the aforementioned places are in telegraphic communication with most parts of Norway during the fishing season, and I have no doubt arrangements could be made for keeping the offices open as late as August 8. The temperature at Vadso is remarkably high, probably between 50° and 60° F. in August (I have known it in the early summer to be 90° F.), and from statistics and all I can learn locally, I think there is every chance of fine weather at that time. I have already paved the

way for an expedition here, and instructed a number of Norwegians in the neighbourhood.

Crossing the Varanger Fjord we come to Bugö, a Lapp fishing station, and within a mile and a half of the central line: the longitude is about 29° 50′, and latitude 69° 58′ Here the duration would be about $1^m\ 40^s$, with nothing to obstruct the view; frequent communication could be had with Vadso at certain times of the day; heliograph signals might be transmitted; there are several sites hereabouts, but one in particular desirable. Baedeker's suggestion, however, that good quarters may be had anywhere hereabouts reads like a fairy tale, and is a pure fiction. But no doubt if arrangements were made beforehand, a structure might be obtained or a place run up. The Bugönæsfjeld I will leave to those who like to be in the clouds! So little is known of it that every map shows it in a different position; but if intrepid mountaineers are fond of carrying half-hundredweights up mountains, there is no reason why they should not have the satisfaction they desire, but they will find no one to do it for them.

In order to distribute the parties and multiply the chances of success, I would suggest some one party proceeding from Vadso to Seida, on the Tana River. This station is a good one for all points except the length of totality, which is only about $1^m\ 12^s$, and has the Sun at an altitude of about $13\frac{1}{2}°$. Polmăk, some 12 miles due south (reached by poling up the river), is not so easily got at, but astronomically better situated, and S.E. of it, about five miles, is a mountain over 1000 feet high; but time did not enable me to explore it. About forty or fifty miles further up this river, in a S.W. direction, is Utsjoki, a place also that might be advantageously occupied in the Russian Lapland. The duration of totality here would be about $1^m\ 26^s$, and the Sun's altitude about 13°; both at Polmăk and Utsjoki camp equipage would have to be taken. Both are in telegraphic communication with Vadso and Vagge, the latter place being at the mouth of the Tana Fjord. Karasjok is astronomically a good place, within four miles of central line, the Sun's altitude being about $12\frac{1}{4}°$ and duration of totality over $1\frac{1}{2}^m$. Much, of course, will depend on the number of observers it is proposed to send out, their powers of endurance, and knowledge of Lappish, Russian, and Norwegian for the east coast expeditions (except at Vardo).

If ladies purpose joining, I would recommend them to go to Bödo, on the west side, or Vardo, or possibly Vadso, on the east coast, on account of the accommodation at the first and third places. I think it might be possible to arrange with the mail steamboat companies to live and feed on board ship (which in this case would be changed every third day) during their entire stay at Bödo or Vadso. I have already been in negotiation with the steamboat companies on this subject. In any case, the lines of communication would be carried out best

by the Norway company's steamers for an eastern expedition, and probably for a western also. (It is quite unnecessary to consult Cook or Gaze on the subject, which would mean an extra cost of 10 or 15 per cent., and it can be done well without.) The Norse steam companies would doubtless also provide a steam launch, and fuel, to keep up communication between the various parties. With proper care and organisation, I think we have every reason to expect that success should crown our efforts; the weather in all the parts I have referred to is likely to be favourable, and the hardships not to be too great for those energetic women who help us everywhere to success. Yet they must be self-reliant in these out-of-the-way districts, and be ready to put up with inconveniences, mosquitoes amongst other pests being plentiful, and rendering one's couch not always a bed of roses.

This eclipse is also visible in Japan, on the Island of Yeso, the duration of totality being longer, and the Sun's altitude greater considerably; and observations on this station I shall be happy to refer to at a later period.

Total Eclipse of the Sun, 1896 *August* 8.

Table of Advantages of Suggested Stations.

Names.	Lat.	Long.	Totality.	Distance C. Line	Altitude of Sun.	Lodging accom.-modation.	Feeling.	Height. Suitable positions.	Description.	Telegraph Station.	Weather.	Communication.	Remarks.
	° ′	°	m s.	Miles.	° ′			Feet.					
Tommen Öe	66 15	12 50	1 10	S. 28	...	Nil	...	...	Island	...	Fair	Difficult, S.	See note (*a*)
Trænen	66 30	12 05	1 31	S. 2	6 21	Nil	...	2000	Island	...	Good	,,	
Oxtinden	66 26	13 11	1 16	S. 24	...	Nil	...	...	Promontory	Yes	Fair	Good, S.	Grono, a steamboat station
Hestmandöe	66 31	12 50	1 25	S. 11	6 40	Fishing	Take some	1700	Island	Near	Good	Fair, S.	
Næsöe	66 35	12 40	1 23	S. 6		Unknown	...	...	Island	...	Good	Good, S.	
Röd Löven	66 42	13 08	1 28	S. 6		Fishing	Arrange	1200	Island	Near	Good	Good, Grono	See note (*b*).
Bolgen	66 48	13 13	1 29	S. 2	to	Nil	Arrange	700	Island	...	Good	Good, Grono	
Melöe	66 49½	13 28	1 27	S. 4		at Grono (near)	Take some	2000	Island	...	Good	Good, Grono	
Kunnen	66 56½	13 33	1 28	N. 3		Yes	Take some	2000	Promontory	Yes	Good	Good, Bödo	
Slöt Öe	66 57½	13 31½	1 27	N. 4	7 16	Lighthouse	Take some	125	Lighthouse Ö	Yes	Good	Fair, Bödo	
Fuglöe	67 03½	13 50	1 24	N. 7	...	Fishing	Arrange	1200	Island	Near	V. Fair	Good, Bödo	
Fleina	67 06	13 55	1 22	N. 10	...	Fishing	Take some	400	Island	Near	Good	Good, Bödo	
Sandhornet	67 06	14 06	1 23	N. 5	...	Yes	Take some	3300–4000	Island	Yes	Good	Easy, Bödo	
Bödo	67 17	14 24	1 21	N. 10	7 45	Very Good	Good	50–400	Neck of land	Yes	V. Fair	Station	

Names.	Lat.	Long.	Totality.	Distance C. Line.	Altitude of Sun.	Lodging accommodation.	Feeling.	Height. Suitable positions.	Description.	Telegraph Station.	Weather.	Communication.	Remarks.
	° ′	° ′	m s	Miles.	° ′			Feet.					
Lande Gode	67 23	14 20	1 27	N. 17	7 44	Unknown	Arrange	500	Island	No	Good	Fair	Beieren Hill, 4000 feet, near Bödo
Vardo	70 21½	31 08½	1 31	N. 10	14 40	Fair	Good	50–150	Island	Yes	Good	Good	
Kilberg	70 16	31 06	1 35	N. 6	14 35	Indifferent	Arrange	350	Promontory	Yes, near	Good	Good	Sandstone rocks
Store Ekkero	70 05	30 10	1 41	N. 1	14 12	Fair	Arrange	50	Mainland & promontory	Yes, near	Good	By road, Vadso	
Vadso	70 04	29 47	1 35	N. 5	13 41	Good	Good	250–450	Mainland	Yes	Good	Good	
Bugönæs	69 58	29 50	1 40	S. 1½	13 40	Tents	Arrange	50	Promontory	Heliograph	Good	Good f. Vadso	Lapp & Finn
Seida	70 15	28 10	1 12	N. 23–27	13 25	Fair	Arrange	200–300	Inland, Hill	Yes	V. Good	Good	Mosquito tents required; mountain 1000 ft., near Seida; 3 sec. longer totality
Polmăk	70 02	28 05	1 21	N. 16	13 23	Fair	Arrange	100–1000	Inland, Hill	Yes	V. Good	Fair	
Utsjoki	69 45	26 48	1 27	N. 13	13 00	Tents	...	150	Inland	...	Good	Difficult	
Karasjok	69 15	24 40	1 31	S. 4	12 20	Unknown	...	200	Inland	...	Fair	More difficult	

On Tana River

(*a*) S. means Selsovig, a steamboat station.

(*b*) In col. 8 "Arrange" means that feeding may be arranged for in part on the spot; "Good" means that Good feeding may be obtained there. Throughout the table the sign ... means "uncertain."

On the Measurement and Reduction of the Plates for the Astrographic Chart. By Professor H. H. Turner, M.A., B.Sc.

1. In a former paper (*Monthly Notices*, liv. p. 11) I briefly indicated a method of rectilinear coordinates, by which the reductions of measures on photographic plates could be made with comparatively little reference to spherical coordinates of any kind, especially the coordinates R.A. and Declination, and thus with very much greater simplicity and rapidity than by other methods. The method is specially applicable to the comparison of one photographic plate with another ; and in this case the introduction of R.A. and Decl. as a medium of comparison simply entails a very large amount of waste labour. For the comparison of a photographic plate with existing meridian or other observations, we naturally cannot escape dealing with R.A. and Decl. at some stage ; but it seems to me that, in view of the fact that the number of stars with which we shall deal photographically will probably enormously exceed the number to be dealt with in other ways, the transformation should be rather that of the comparatively few existing measures of R.A. and Decl. into rectangular coordinates, suitable for comparison with photographic measures, than of the numerous photographic measures into R.A. and Decl.

2. In a subsequent paper (*Monthly Notices*, liv. p. 489) I gave an example of such a transformation of R.A. and Decl. into suitable rectangular coordinates, whereby the measures of a number of plates of the *Pleiades* could be "reduced"—signifying by the term "reduction" the correction for errors of orientation, scale value, refraction, aberration, &c.—with very little labour. The Astronomer Royal and Mr. Dyson gave last month (*Monthly Notices*, lv. p. 60) an example of the facility with which four photographic plates could be compared *inter se*. I have also been privileged to see a paper which Captain Hills is communicating to the Society this month on the determination of longitudes by photographs of the Moon and stars, in which he expresses very kindly his indebtedness to the method of rectilinear coordinates for reducing photographs. Perhaps it is not too much to hope that, as its advantages become better known, the method of rectilinear coordinates for reducing, *and expressing the results of*, photographic measures will be generally adopted.

3. The object of the present paper is to give at greater length detailed directions for measuring and reducing the plates of the Astrographic Chart in accordance with the principles of this method. Much experimental work has been done both at the Royal Observatory, Greenwich, and the University Observatory, Oxford, the results of which it seems advisable to set down for the criticism, or the information, of others. It is quite probable that improvements may yet be suggested in various directions ;

0

for it takes some time to develop a new method, as we have found already; and if some of the following statements appear a little arbitrary it is for the sake of brevity, and not from any desire to assume that the processes have taken final shape. I should wish here to record my indebtedness to the Astronomer Royal for the interest he has taken in the new method from the first, and for his valuable suggestions and criticism; also to Mr. Dyson for similar suggestions.

4. *Measures.*—Theoretically the only requisite condition is that these should be *truly rectilinear*. Any micrometer which secures this is suitable. The only conditions which will further define the micrometer are practical considerations, and the form which experience has suggested as best suited to the special work of the Astrographic Chart is that alluded to in the paper by the Astronomer Royal and Mr. Dyson (*Monthly Notices*, lv. p. 60), in which the stars are referred to the lines of the *réseau* by means of a glass-scale in the eyepiece.* This secures

(1) Rapidity, the turning of a micrometer screw being avoided.

(2) An accuracy which is found to be *sufficient* while avoiding the use of too many decimal places, which would add seriously to the work.

(3) Convenience to the observer, it being no longer necessary to withdraw the eye from the microscope to read the screw—a tiring operation.

5. A diagram of the scale is given in Plate 3. The divisions on the scale represent each 0·01 of a *réseau* interval, or 3″·0; and readings are made by estimation to tenths of these, or 0″·3. In what follows measures are always expressed in *réseau* intervals. The readings are made thus: by the slow motions the star to be measured is brought centrally over the intersection of the scales; and the readings of the scale are then observed where it is cut by the four sides of the *réseau* square in which the star-image lies.

6. A difficulty of some importance in the adoption of this form of micrometer is that of making the scales. Mr. Simms has been successful in some instances though not in others, and as yet the scale can scarcely be described as a commercial article. It is apparently a danger that in cutting divisions plain enough to be seen, and so close together as above-mentioned, the surface of the glass will break up. In trying to avoid this disintegration the divisions are sometimes cut so lightly as to be difficult to see in the microscope; and the difficulty of seeing the divisions is tantalizingly greatest when the star images are just in good focus. The grain of the photographic film seems then to mix

* The authors have kindly credited me with the suggestion that a scale should be used instead of a micrometer screw; but the determination of the particular form is due to the Astronomer Royal and Mr. Simms.

itself up with the divisions and obscure them, although a turn of the focussing screw makes them distinct. We have, however, one excellent scale at Oxford, and there is another at Greenwich, so that the instrumental difficulties have been surmounted in special cases, and it only remains to make a certainty of surmounting them always. Meanwhile a very workable scale can be made by drawing carefully on a large sheet of card a magnified representation of it, and photographing this representation at the proper distance. A photographic scale of this kind has been used with satisfactory results at Oxford.

7. *Error of Runs.* If all adjustments were perfect, the readings of the scale at the points where it cuts the *réseau* lines should be identical—*i.e.* the distance between two *réseau* lines should always be 1·000. Such perfection is not attainable in practice, and we have to consider

(*a*) How to make the difference between the readings as small (on the average) as possible.
(*b*) How to deal with residual differences.

To consider (*a*) first. The scale may be cut with the greatest care by the maker to suit the particular microscope, and yet different conditions of temperature, &c., may make a sensible "error of runs," so that the readings of the scale for the two *réseau* lines differ systematically over the plate by (say) ·003 (=0″·9). To obviate this there should be a screw adjustment *not only for the whole microscope with reference to the plate, but for the objective of the microscope with reference to the glass-scale.* Such adjustments are of course the business of the instrument maker. Mr. Simms has furnished them in the Greenwich and Oxford instruments, and if these are properly used before commencing measurement on a plate, the "error of runs," for any given *réseau* square, should never exceed ·003. That it may be so large in individual cases is due to errors such as

Errors of the *réseau* lines,
Distortion of the photographic film,
Curvature of the photographic plate,
Accidental errors of bisection, &c.

In the case of the curvature of the plate the remedy is comparatively simple: by means of the adjustments above mentioned we focus and adjust for runs afresh; or focussing afresh, we apply a correction for runs. In the other cases we must either undertake elaborate investigations or treat the errors as accidental. For reasons that cannot be here fully dealt with the remaining errors will be treated as accidental; and thus we have three sources of *accidental* error as against one which represents a *real* correction for runs.

I proceed to show how, so long as an accuracy of 0·001 (=0″·3) for the final reading is considered sufficient, the final reading may

be set down at once, without entering the readings at both *réseau* lines and computing a mean, corrected for runs.

We have remarked above that the difference between the two *réseau* readings should not exceed ·003—*i.e.* should be either ·000, ·001, ·002, or ·003. Suppose the difference to be ·002, *i.e.* let the readings be x and $x + ·001$. If the difference is *wholly accidental*, the adopted readings should be $x + ·001$. If the difference, however, is due to a *real error of runs*, then the adopted reading should be :

x	from $x = 1·000$	to	$x = ·750$
$x + ·001$	,,	$x = ·750$	,,	$x = ·250$
$x + ·002$	,,	$x = ·250$	,,	$x = ·000$

the same reading ($x + ·001$) as in the case of accidental difference holding over the middle half of the scale, but being modified to agreement with the reading at the line *near the star*, when the star is within ·250 of either line. Finally, if we regard the error of runs as partly real and partly accidental, we should adopt the reading $x + ·001$ over a wider range, and restrict the adoption of x or $x + ·002$ to cases when the star is nearer still to the *réseau* lines.

Of the other values for runs likely to occur, that of ·000 needs no comment, and those of ·001 and ·003 will resemble that of ·002 with a slight complication as to raising figures. It need not be explained at greater length that a practical rule which will obviate any separate entry of the two readings, and consequent computation of, and correction for, runs, is :

Take the mean between the two readings (mentally), with an inclination towards the reading at the line nearer the star.

To those who are inclined to criticise this rule as rough and inaccurate, I would reply that no doubt a little accuracy is sacrificed, but a very large number of figures are saved thereby ; and, after all, it may be questioned how far the apparent loss of accuracy is real.

8. *Expression of the Results.*—The coordinates of a star may be expressed in various ways—in revolutions of a micrometer screw, in reputed seconds or minutes of arc, or in *decimals of a réseau interval*. It will be gathered from what precedes that it is proposed to adopt as the standard method of expression the *decimals of a réseau interval to three places*—that is, to estimated tenths of a division of the glass-scale. By making the correction for runs mentally the coordinates are set down at once in this form, say as 13·342 and 21·687. By thus taking a little care in the arrangement of apparatus, &c., ten figures suffice to reach and record a result over which fifty or sixty figures may easily be expended. The importance of this saving of figures in *every item* of such a large piece of work can scarcely be over-estimated. It remains, however, to adopt some convention for the integers. The *réseau* lines on many of the *réseaux* are numbered from

1 to 27, and they cannot be made always to agree with increasing R.A. and Decl. when photographs are taken both E. and W. of the pier. It will be better on the whole to neglect them and adopt a scale from 0 to 26, agreeing in one case with increasing R.A. and in the other with increasing Declination.

9. *Standard Coordinates.* — For an ideally-perfect set of measures on an ideally-perfect plate, oriented for 1900·0, it seems to me that the coordinates of stars expressed in this way might well be left as they are. The small number of stars on the plate whose R.A. and Decl. have been, or will be, measured in other ways can be compared with the measures on the plate with much less labour if their positions are converted into the above "standard coordinates" than if the photographic measures are all reduced to R.A. and Decl. for a given epoch ; and further, any future photographs will be far more speedily compared with the plate without any reference to R.A. and Decl. at all.

Further, the fact that no plate is ideally perfect, either in the taking or the measuring, does not introduce any serious difficulty, for I have endeavoured to show that its defects, both accidental and systematic, can be simply expressed by linear formulæ. The coefficients of these formulæ are to be found from the known stars on the plates or from comparison with other plates, and while it will be convenient to make at once an approximate determination of them from the material at command, the final determination may be deferred. The work of finding the constants is not heavy, and may indeed be repeated several times without much waste of labour. The final determination should be based on the discussion of a number of overlapping plates—to fix the ideas, say a whole zone taken together—each plate being connected with its neighbour by two others, viz. one in the zone north and one in the zone south.

10. *Choice of Standard Coordinates.*—But if we stop here there will be an ambiguity. Every star occurs generally on two plates, and thus will have two pairs of standard coordinates in the sense of the last paragraph. Are both to be recognised? This would lead to some confusion. If a choice is to be made, what shall be the convention? The Astronomer Royal has proposed (and the proposition seems thoroughly satisfactory) that the coordinates in the *north* half of an ideal plate should stand, and those on the *south* half be converted into the corresponding coordinates of the overlapping plates whose centres are in the zone 1° south. This convention will be adopted for the present. It would seem advisable, however, at least in the final presentation of results, to subtract the number 13 from all the y coordinates, so that they may run from 0 to 13, and not from 13 to 26. In the southern hemisphere it should be the *south* half of each plate which is left untouched, if the same tables are to be available as in the northern hemisphere ; the measures to be modified are, in fact, those in that half remote from the pole in each case.

11. *Transformation of Coordinates in the half of a Plate remote from the Pole.*—To save circumlocution, let us consider a plate in the north hemisphere; and let it be an *ideal* plate, *i.e.* let us first neglect refraction, aberration, errors of orientation, photography, and measurement; and let the coordinates of its centre be $20^h\ 8^m$, $+26°$. The S.W. quarter is overlapped by the N.E. quarter of the plate whose centre is at $20^h\ 4^m$, $+25°$; and the S.E. quarter is overlapped by the N.W. quarter of the plate whose centre is at $20^h\ 12^m$, $+25°$. It is required to transform the measured coordinates on the first plate so as to accord with those measured on these two overlapping plates. Let $(x_1\ y_1)$ be coordinates on the first plate, $(x_2\ y_2)$ on the second, and $(x_3\ y_3)$ on the third. The formulæ, as corrected by Mr. Dyson in *Monthly Notices* (liv. p. 573), will not immediately give us the relations between $(x_2\ y_2)$ and $(x_1\ y_1)$, because we are now measuring from the *corner* of the *réseau* instead of from the *centre*—but the transformation need not be given at length. The relations will be similar to the following, which, though not correct, were used in the work quoted in paragraphs 12 to 16, and will quite well serve the purpose of the present paper:

$$x_2 - x_1 = -\cdot00055x_1 + \cdot00759y_1 + 10\cdot688 + \cdot000025x_1y_1 + \cdot000023x_1^2$$
$$y_2 - y_1 = -\cdot00740x_1 - \cdot00056y_1 + 12\cdot138 + \cdot000023x_1y_1 + \cdot000025y_1^2$$

It will be seen that these expressions are not very difficult to calculate, and that the terms are small, excepting only the constant terms and the terms $+\cdot00759y_1$ in $x_2 - x_1$ and $-\cdot00740x_1$ in $y_2 - y_1$. Since x_1 and y_1 may be as large as $14'$, these latter may amount to one-tenth of a *réseau* interval, or 30 seconds of arc; and this limit is larger for plates of greater declination. But in view of the extensive nature of the work and the importance of saving labour, especially if it can be seriously reduced for every item, I have given some attention to methods of reducing the labour of applying these corrections within the smallest possible limits; and venture to hope that the result of the inquiry, as indicated in the next few paragraphs, will be found conducive to this end.

12. *Practical Method of applying the Corrections.*—It may not be out of place to give the successive steps by which the final method was arrived at. The first step consisted simply in dividing the corrections into two parts: expressions large enough to require logarithms or Crelle's Tables, and others manageable by mechanical or diagrammatic means. The former were simply the large terms above noted ($+\cdot00759y_1$ and $-\cdot00740x_1$) or the major parts of them; and as a first essay the parts $+\cdot007y_1$ and $-\cdot00\ x_1$ were selected for separate application, involving little arithmetic. This left

$$-\cdot00055x_1 + \cdot00059y_1 + \cdot000025x_1y_1 + \cdot000023x_1^2$$

and

$$-\cdot00040x_1 - \cdot00056y_1 + \cdot000023x_1y_1 + \cdot000025y_1^2$$

for application by mechanical means (omitting the constant terms 10·688 and 12·138). A series of curves was drawn corresponding to the values ±·0005, ±·0015, ±·0025, &c., of these expressions, by use of cross-ruled paper; and it was proposed to apply the uniform corrections ·000, ±·001, ±·002, &c., to stars falling in the spaces between these curves, as shown in fig. 1, Plate 4.

13. The next step was taken more or less accidentally. The curves were plotted by calculating the value of y_1 in the first case, and of x_1 in the second, for different values of x_1 and y_1 respectively. Taking the first case alone for brevity, we have

$$y_1 = \pm\cdot0005/(\cdot00059+\cdot000025x_1) + (\cdot00055x_1-\cdot000023x_1^2)/(\cdot00059+\cdot000025x_1)$$

and the calculations for $x_1=0$, 1, 2, 3, &c., were found to occupy more time than was convenient.

To reduce this labour it was proposed to apply separately, not the expression $+\cdot007y_1$ simply, but the expression $+\cdot00819y_1$, leaving for diagrammatic treatment

$$-\cdot00055x_1-\cdot00060y_1+\cdot000025x_1y_1+\cdot000023x_1^2$$

which can be put into the form

$$-\cdot000001\,(23x_1+25y_1)\,(24-x_1),$$

and equating this to (say) ±·0005, the resulting curves are easily calculated from the equation

$$y_1 = \pm\frac{20}{x_1-24}-\frac{23}{25}x_1$$

14. In taking this step, not only was the labour in calculating the curves reduced as expected, but the curves covering the quarter-plate in question were *much fewer in number* (see fig. 2), so that the variety of separate corrections to be applied was much less. This at once suggested the third step, viz. an inquiry what part of the coefficient of y_1 in the original expression (which may be written, after multiplying by a power of 10,

$$-550x_1+7590y_1+25x_1y_1+23x_1^2)$$

should be applied separately so as to leave for diagrammatic application an expression yielding the fewest number of curves over the actual quarter-plate?

15. This is practically the following question in geometry: there is a series of hyperbolas

$$-550x+\lambda y+25xy+23x^2=\pm500\,(2n+1)$$

where n is an integer, and λ a variable parameter. Find the

Fig. 1.

FIRST FORM OF CORRECTION.

$(-55x+59y+2{\cdot}3x^2+2{\cdot}5xy)$=Const.

(Zone +26° only).

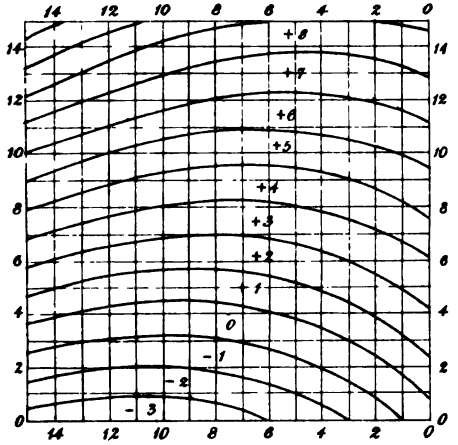


Fig 2.

SECOND FORM OF CORRECTION

$(23x+25y)(x-24)$ = Const.

(Zone +26° only.)

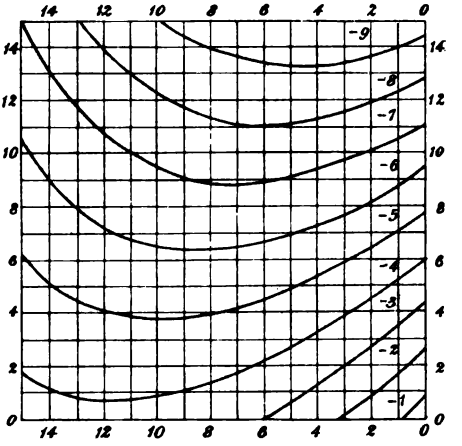


Fig. 3.

THIRD FORM OF CORRECTION

$-55x-21y+(23x+25y)x$=Const

FEW CURVES (Zone +26° only)

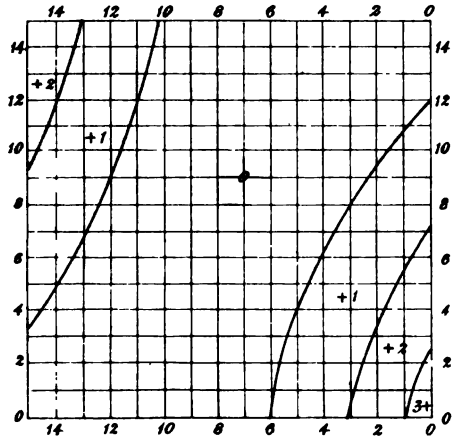
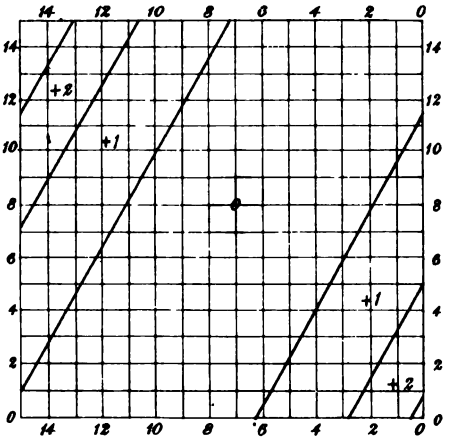


Fig. 4.

FINAL FORM OF CORRECTION.
FOR ALL ZONES.

$24\{(x-7)+\frac{1}{2}(y-7)\}^2$ = Const.



value of λ which will make the number of curves crossing a given square

$$[x=0 \text{ to } x=14\,;\ y=0 \text{ to } y=14]$$

a minimum. It is easily seen that the common centre of the hyperbolas must coincide with the centre of the square, and we were thus led to the value

$$\lambda = -210,$$

which gives the curves shown in fig. 3. It will be seen that the number of curves is now very small, and the application of the correction can be made with very little labour indeed.

16. A fourth step which has been taken is open to criticism because of a slight sacrifice of accuracy in order to save labour. Personally, I think the sacrifice quite justifiable, but others may be of a different opinion. It is to be remarked that the processes indicated above are strictly accurate.

The fourth step consists in throwing the original expression into the form

$$\cdot 000023\left\{(x-7)+\frac{25}{46}(y-7)\right\}^2$$
$$-\cdot 000023\times\left(\frac{25}{46}\right)^2(y-7)^2$$
$$+\text{linear terms}.$$

The linear terms are to be applied separately, as will presently be mentioned. The term

$$-\cdot 000023\times\left(\frac{25}{46}\right)(y-7)^2$$

is to be *neglected*, its greatest value over the region

$$y=0 \text{ to } y=14$$

being

$$\cdot 000023\times 14=\cdot 0003$$

and this is the slight sacrifice of accuracy above mentioned.

The first term is to be diagrammatically applied, and being a perfect square its contour lines are *straight* instead of being hyperbolas, and thus very easily drawn by a ruler from two points only on each.

17. Further, it may be remarked that the coefficients $\cdot 000023$ and $\cdot 000025$ which occur throughout the above expressions, are the particular values of k and l for the zone $+26°$; k and l being (as in *Monthly Notices*, liv. p. 11) the coordinates of the centre of one plate or another.

These coordinates are nearly equal, except for the zones where

a change in the number of plates is made ; and if we take them both ·000024 *for all zones* we shall lose very little in accuracy, and have a *single diagram for all zones.* This single diagram is shown in fig. 5. The diagrams throughout refer to the expression for x_2-x_1 ; corresponding diagrams for y_2-y_1 may easily be constructed ; and in the case of the last may be obtained by simply turning it through a right angle.

18. The application of part of the correction by any of these diagrams leaves a linear part to be applied numerically. The first three leave merely a multiple of y_1, but the fourth (which I regard as the best) leaves multiples both of x_1 and y_1. It was not until after a little experience in comparing plates that it occurred to me that these linear remainders need not be actually applied to individual measures, but may be subtracted algebraically from the linear expressions ultimately found by comparing two plates, as explained in the next paragraph. The final outcome of the paragraphs §12–§18 is thus as follows :

To the measured coordinates on the quarter-plate to be transformed apply corrections +·001, +·002 *or* +·003, *according to the diagram of fig.* 5 *for the* x *coordinate and a corresponding diagram for the* y *coordinate, the greater part of the measures requiring no correction. The measures are then ready for linear comparison with the overlapping quarter-plate.* Those who object to the slight inaccuracy of the diagram 5 should use diagram 4, which is a little more laborious to construct, but quite accurate.

19. *Deferred Application of Linear Terms.*—After the application of corrections, as in the last paragraph, we have now two quarter-plates of measures of the same stars *corrected for difference of plane of the plates,* and differing theoretically only in orientation and position in their common plane. Practically there are also discrepancies due to refraction, aberration, scale value, &c. The existence of these latter sources of difference, which have hitherto been deliberately neglected, will not sensibly affect the transformation of the last paragraph, unless the plates have been taken in serious disregard of the resolutions of the Astrographic Congress and Committee.

The measures on one plate will thus be linear functions of the measures on the other : that is, we shall have

$$x_2-x_1(\text{corrected}) = (a+\alpha)x_1+(b+\beta)y_1+c+\gamma$$
$$y_2-y_1(\text{corrected}) = (d+\delta)x_1+(e+\epsilon)y_1+f+\zeta$$

where α, β, γ, &c., refer to the remaining part of the theoretical expressions for transforming an ideal x_1 and y_1 into an ideal x_2 and y_2 ; and a, b, c, &c., refer to the errors of refraction, aberration, orientation, &c. In dealing with the measures of individual stars, however, there is no need to distinguish between a and α, b and β, and so on ; we may write

$$x_2-x_1(\text{corrected}) = Ax_1+By_1+C$$
$$y_2-y_1(\text{corrected}) = Dx_1+Ey_1+F$$

and find from the measures, by least squares or otherwise, the coefficients A, B, C, D, E, F, which we may then analyse into their constituents, α, β, γ, &c., known from theory, and a, b, c, &c., which inform us of the accidental errors. The analysis is thus performed for 6 coefficients only instead of for 50 or 100 stars—another great saving of labour.

20. *Practical Method of Solving the Equations.*—The special form of the equations has suggested a special method of dealing with them. It will be found that from three or four stars we can obtain an approximate solution of the form

$$A = E = 0,\ B = -D,\ C = C',\ F = F',$$

where, moreover, B and D are only given to three decimal places, C′ and F′ to one. Thus in the example given below, the following approximate solution was found:

$$A = E = 0,\ B = -D = -\cdot011,\ C' = 10\cdot850,\ F' = 11\cdot930$$

By means of an easily constructed table, the expressions $By_1 + C'$, $Dx_1 + F'$ can be quickly applied to the coordinates x_1 and y_1 (corrected); and their differences from x_2 and y_2 will then rarely exceed ·006, and will in general be ·000, $\pm$·001, $\pm$·002, or some very small quantity. The differences become, in fact, like residuals, and can be treated by any of the rapid methods applicable to residuals. The mean of the differences for all the stars in any portion of the plate can almost be taken mentally, and the mean coordinates of the stars on this portion (not required with great accuracy) can be estimated at sight. Thus the normal equations for a final solution can be written down very quickly, and as quickly solved. The deduced linear expressions representing the differences are also very simple, and can be easily compared with them, which completes the whole comparison.

21. *Practical Example of Reductions.*— Such a description of new processes would of course be incomplete without an example, and the following is taken from the first pair of plates compared at Oxford. Twenty-one stars have been selected from the quarter-plates 126 and 444 quite at random, as sufficient to show the method. To give the measures of the whole 85 stars common to these quarter-plates would take too much space.

The coordinates of the centres of the plates are

Plate 126 (Taken 1892 Aug. 12)	R.A. $20^h\ 8^m$	Decl. $+26°$
Plate 444 (Taken 1893 Aug. 15)	R.A. $20^h\ 4^m$	Decl. $+25°$

Table of reduction of Plate 126 (*S.W.*) *to Plate* 444 (*N.E.*)

x coordinate.

1. No. for Ref.	2. Measure on Plate. 444 ($=x_2$)	3. Plate. 126 ($=x_1$)	4. Small Corr. to 126.	5. Approx. Solution.	6. 126 Corrected.	7. Excess of x_2 $=\delta x_1$	8. Excess from Formula.	9. C−O.
1	24·590	13·892	+·002	−·149	24·595	−·005	−·003	+·002
2	22·777	12·080	+ 2	−·153	22·779	− 2	− 3	− 1
3	20·223	9·514	+ 1	−·139	20·226	− 3	− 2	+ 1
4	25·188	14·439	+ 2	−·101	25·190	− 2	0	+ 2
5	22·102	11·347	+ 1	−·097	22·101	+ 1	0	− 1
6	19·550	8·784	...	−·086	19·548	+ 2	0	− 2
7	18·211	7·501	...	−·137	18·214	− 3	− 2	+ 1
8	15·940	5·220	...	−·132	15·938	+ 2	− 2	− 4
9	14·505	3·806	...	−·146	14·510	− 5	− 3	+ 2
10	12·972	2·241	...	−·117	12·976	− 4	− 2	+ 2
11	14·270	3·505	...	−·083	14·272	− 2	0	+ 2
12	18·591	7·819	...	−·077	18·592	− 1	0	+ 1
13	15·084	4·283	...	−·052	15·081	+ 3	+ 2	− 1
14	14·634	3·797	+ 1	−·017	14·631	+ 3	+ 3	0
15	17·165	6·342	...	−·032	17·160	+ 5	+ 3	− 2
16	20·120	9·299	...	−·032	20·117	+ 3	+ 0	+ 1
17	21·424	10·601	...	−·031	21·420	+ 4	+ 2	− 2
18	24·495	13·671	...	−·030	24·491	+ 4	+ 3	− 1
19	24·685	13·881	+ 1	−·050	24·682	+ 3	+ 2	− 1
20	25·469	14·687	+ 1	−·069	25·469	0	+ 1	+ 1
21	22·466	11·680	...	−·068	22·462	+ 4	+ 1	− 3

y coordinate.

1. No. for Ref.	2. Measure on Plate. 444 (=y_2)	3. 126 (=y_1)	4. Small Corr. to 126.	5. Approx. Solution.	6. 126 Corrected.	7. Excess of y_2 = δy_1	8. Excess from Formula.	9. C−O.
1	25·649	13·543	+·002	+·153	25·648	+·001	+·005	+·004
2	26·000	13·911	+ 2	+·133	25·996	+ 4	+ 4	0
3	24·706	12·648	+ 1	+·105	24·704	+ 2	+ 3	+ 1
4	21·328	9·213	+ 1	+·158	21·322	+ 6	+ 6	0
5	20·846	8·765	...	+·124	20·839	+ 7	+ 5	− 2
6	19·878	7·827	...	+·096	19 873	+ 5	+ 4	− 1
7	24·548	12·511	+ 1	+·083	24·545	+ 3	+ 2	− 1
8	23·982	11·971	...	+·057	23·978	+ 4	+ 1	− 3
9	25·313	13·322	+ 1	+·042	25·315	− 2	0	+ 2
10	22·606	10·630	...	+·025	22·605	+ 1	0	− 1
11	19·507	7·516	...	+·039	19·505	+ 2	+ 2	0
12	19·011	6·974	...	+·086	19·010	+ 1	+ 4	+ 3
13	16·741	4·744	...	+·047	16·741	0	+ 3	+ 3
14	13·534	1·540	+ 1	+·042	13·533	+ 1	+ 3	+ 2
15	14·963	2·933	...	+·069	14·952	+ 11	+ 4	− 7
16	14·847	2·791	...	+·102	14·843	+ 4	+ 5	+ 1
17	14·913	2 841	...	+·117	14·908	+ 5	+ 6	+ 1
18	14·830	2·722	...	+·150	14·822	+ 8	+ 8	0
19	16·592	4·482	...	+·153	16·585	+ 7	+ 7	0
20	18·433	6·314	...	+·162	18·426	+ 7	+ 7	0
21	18·261	6·172	...	+·128	18·250	+ 11	+ 6	− 5

The *first* column gives a number for reference.

The *second* column gives the measured coordinate on plate 444, N.E. quarter ; these measures are to remain untouched.

The *third* column gives similarly the measures on plate 126 (S.W. quarter), which are to be corrected to conformity with 444. We thus apply the small correction in the *fourth* column, from the diagram in fig. 5. It will be seen at once how small and simple this correction is, though, of course, quite sensible. It is sufficient to set down the correction at present ; it may be added in with column 5.

Before proceeding further we now form an approximate solution from four stars only. The four selected are (1), (9), (13), and (19), and we have

	x_2	x_1	x_2-x_1	y_2	y_1	y_2-y_1
(1)	24·590	13·894	10·696	25·649	13 545	12·104
(9)	14·505	3 806	10·699	25·313	13·323	11·990
(13)	15·084	4·283	10·801	16·741	4·744	11·997
(19)	24·685	13 882	10·803	16·592	4·482	12·110

The values of x_2-x_1 for (1) and (19) differ by ·107 ; and (in this approximate solution) this difference is to be assumed wholly due to the difference in value of y_1 (see paragraph 20).

Thus we have

$$B = -\frac{\cdot 107}{9\cdot 063} = -\cdot 0118$$

From the pair of stars (9) and (13) we should get

$$B = -\frac{\cdot 102}{8\cdot 579} = -\cdot 0119$$

Similarly from the pair (1) and (9) we get

$$D = +\frac{\cdot 114}{10\,088} = +\cdot 0113$$

and from the pair (13) and (19)

$$D = +\frac{\cdot 113}{9\cdot 599} = +\cdot 0118$$

The mean of these (numerically) is ·0117.

The values of C and F are found from the formulæ

$$C = x_2 - x_1 - By_1$$
$$F = y_2 - y_1 - Dx_1$$

and are as follows for the four stars :

	C	F
(1)	10·855	11·941
(9)	10·854	11·945
(13)	10·856	11·947
(19)	10·856	11·947

the mean values being 10·855 and 11·945.

Now it is open to us to apply these corrections as exactly as we please ; only it is to be remembered that they are not *final* and are merely meant to save labour by transforming x_1 and y_1

into numbers nearly resembling x_2 and y_2. We shall always save labour by retaining only two decimals in C and F, and only three in B and D, as above. We thus apply the corrections

$$10{\cdot}850 - {\cdot}0110y_1 \text{ to } x_1$$

and

$$11{\cdot}950 + {\cdot}0110x_1 \text{ to } y_1$$

The application may be performed in a variety of ways, *e.g.* by making a special table, or by using Crelle. Different methods will probably be found advantageous in different zones, for the coefficients B and D will vary considerably in magnitude.

Returning now to the table, the variable parts of these corrections are given in the *fifth* column under the heading "Approximate Solution."

In the *sixth* column the sum of columns 3, 4, and 5 is given, showing a corrected value of x_1 nearly equal to x_2.

The *seventh* column is the difference of columns 6 and 2; and gives the residual differences, which are to be discussed by the method of least squares or its equivalent. The process of approximate correction previously applied in no way invalidates the application of the rigorous method of least squares if it should be deemed advisable to use it; but the following process (due to Mr. Dyson) will probably be found sufficient, and is much shorter and simpler:

Stars 1 to 6 have $x_1 > 7$, $y_1 > 7$
" 7 " 11 " $x_1 < 7$, $y_1 > 7$ (approx.)
" 12 " 15 " $x_1 < 7$, $y_1 < 7$ (approx.)
" 16 " 21 " $x_1 > 7$, $y_1 < 7$

The *sums* of these groups give

No. Stars.	x_1	y_1	δx_1	δy_1
6	70·0	65·9	−·009	+·025
5	22·3	56·0	−·012	+·008
4	22 2	16·2	+·010	+·013
6	73·8	25·3	+·012	+·042

whence we obtain quickly the *mean* quantities for the N. half of the plate, the S. half, the E. half, and the W. half as follows:

N. half	8·4	11·1	−·0019	+·0030
S. half	9·6	4 2	+·0022	+·0055
E. half	12·0	7·6	+·0003	+·0056
W. half	4·9	8·0	−·0002	+·0024

These give four pairs of equations, the first pair being

$$8{\cdot}4a + 11{\cdot}1b + c = -{\cdot}0019$$
$$8{\cdot}4d + 11{\cdot}1e + f = +{\cdot}0030$$

and these are readily solved. We first find

$$a = +{\cdot}00004,\ b = -{\cdot}00053$$
$$d = +{\cdot}00047,\ e = -{\cdot}00025$$

and substituting these in the four pairs of equations, we obtain the following values for c and f:

c	f
+·0039	+·0018
+·0039	+·0019
+·0038	+·0017
+·0039	+·0021

a sufficiently good accordance. The numerical values of the expressions

$$+{\cdot}00004x_1 - {\cdot}00053y_1 + {\cdot}0039$$

and

$$+{\cdot}00047x_1 - {\cdot}00025y_1 + {\cdot}0019$$

were taken out from a simple diagram, and are entered in the *eighth column* of the table. The differences between these theoretical expressions and the observed differences in column 7 are shown in the *ninth column*.

These final residuals rarely exceed ·002 numerically (= 0″·6). On examining the measures which give larger residuals it is generally found that a careful remeasure made the discrepancy disappear. The residual ·007 in the y coordinate is owing to a mistake of ·010 ; and this might have been suspected and corrected earlier. But as the present example is intended rather to illustrate the *method* than to show the final accuracy attainable (which will no doubt improve with practice), the figures have not been altered. The measures were, as above remarked, the first made at Oxford with a scale ; and were, moreover, made with a wooden model of the apparatus with coarse screws for slow motions, while Mr. Simms was making the finished apparatus. But even under these conditions the mean residual is only $\pm$ ·0016 for x and $\pm$ ·0017 for y.

The final formulæ for the reduction of x_1 and y_1 to accordance with x_2 and y_2 are thus :

$$\begin{aligned} x_2 - x_1 &= -{\cdot}011y_1 + 10{\cdot}850 \\ &\quad + {\cdot}00004x_1 - {\cdot}00053y_1 + {\cdot}0039 \\ &= +{\cdot}00004x_1 - {\cdot}01153y_1 + 10{\cdot}8539 \\ y_2 - y_1 &= +{\cdot}011x_1 + 11{\cdot}950 \\ &\quad + {\cdot}00047x_1 - {\cdot}00025y_1 + {\cdot}0019 \\ &= +{\cdot}01147x_1 - {\cdot}00025y_1 + 11{\cdot}9519 \end{aligned}$$

Now the theoretical expressions, due to the ideal geometrical conditions, are

$$x_2 - x_1 = -\cdot00006x_1 - \cdot00753y_1 + 10\cdot8849$$
$$y_2 - y_1 = +\cdot00753x_1 + \cdot00005y_1 + 11\cdot9436$$

and thus the expressions representing refraction, aberration, orientation error, &c., &c., are

$$x_2 - x_1 = +\cdot00010x_1 - \cdot00400y_1 - \cdot0310$$
$$y_2 - y_1 = +\cdot00394x_1 - \cdot00020y_1 + \cdot0083$$

22. In the foregoing paragraphs I have endeavoured to show how, if the rectilinear coordinates of stars on two overlapping photographic plates are measured by a simple and rapid process, they may, also by a simple and rapid process, be compared. Further, that in the case of two plates taken at an interval of 12 months, the comparison shows that there is nothing seriously wrong with any of the measures: that in the case of twenty-one stars taken at random, and measured with a new and rough apparatus by unskilled measurers, the differences rarely exceed ·003 (= 0″·9). It needs no further comparison with known places to show that in measuring photographic plates in this way we are measuring something real and tangible. It is certain that we can arrive at results which compare favourably with meridian observations by processes similar to that above indicated. And even by such processes the measurement and reduction of the plates will take *far longer* than the obtaining of them.

On the other hand, if we aim at a higher order of accuracy, consider how many different sources of error must be carefully investigated. The following list is, if anything, incomplete:

Errors of the *réseau*, errors of the measuring screw or scale, errors in raising figures, distortion of the film, curvature of the plate, optical distortion of the lens, personality in bisecting images, centring of elongated images, proper motions of the stars, to which may be added the accidental errors naturally appertaining to more complicated calculations. Most of these, if not all, must be separately investigated if we aim at a higher order of accuracy than is above indicated; and it would seem doubtful, not only when the work would be finished, but when we should be in a position to commence it.

23. If it occasions surprise that the necessity for some simple and rapid process should be so strongly insisted on, I would briefly call attention to the following facts and figures:

The first tentative proposals for measuring the plates were made in the first number of the *Bulletin du Comité Permanent* (1888 March), by Dr. Gill. They were necessarily quite tentative, and their main object was to initiate a discussion. Dr. Gill mentions three methods of procedure —

(1) The method of rectangular coordinates (*i.e.* that which forms the basis of the present paper).
(2) The method of distance and position-angle.
(3) The parallactic method of measuring R.A. and Declination direct.

That Dr. Gill should immediately dismiss the first method with the comment "that it is much inferior to the second, and does not even offer the advantages of easy reduction," is merely (if I may be allowed the expression) an indication that we have learnt something in the last six or seven years. M. Bakhuyzen ventured to differ from Dr. Gill soon afterwards.

Dr. Gill proceeded to propose a scheme for measurement, involving a permanent Bureau Central, with a staff of twenty-two people, and a budget of 250,000 francs per annum, at least. I took some share in opposing this scheme as too impractical, because of its magnitude. It aimed at getting the most out of the plates possible: it was a *maximum* programme. But the principle of limiting work to what can be accomplished, instead of aiming at what we should hope for, is not new. In meridian work, for instance, observations are limited to three for each star, though a much greater accuracy could be got by making more. The object of the present paper is to suggest a *serious* limitation of the work, without so seriously diminishing its value.

As a second term of comparison we may take the facts given in the published Report of the Paris Observatory for 1893. Mdlle. Klumpke, with a staff of four ladies, measured seventy-two plates in the year on the plan developed with considerable skill by M. Lœwy and MM. Henry. At this rate it will take the Paris Observatory *eighteen* years to measure the 1,300 plates taken at Paris alone. But the Paris Observatory is a strong one, one of those that should quickly finish their own work and help others; it can devote five people specially to the work of measurement. The whole staff of the Oxford Observatory consists of three people, including myself—for University work, taking the plates, and measuring. How much longer then shall we take on such a plan to measure and reduce our plates?

Some serious curtailing of the work is necessary; push the curtailing indicated above as far as it will go, and I believe the work will be found to strain the utmost energies of the astronomical world to get it done in reasonable time. I may, perhaps, without further explanation, conclude this paper with an indication of a

Minimum Programme.

(1) Measure, by referring to the *réseau* lines, *one* bisection of *one* image per star, about 200 stars per plate (100 would be better). Record the measures as simply as possible.

(2) Put almost all reductions aside with a view to getting

these measures completed for the whole area assigned to your observatory within as few years as possible. We have no information how long photographic plates will last. The reductions have been shown to be simple.

(3) When opportunity offers, compare plates by the above method so as to see that no serious error has crept in accidentally. Ordinarily the plates are good enough if they can be measured.

On the Need and Usefulness of Co-operation in Meridian Observation. By Truman Henry Safford.

The following paper grew out of my own experiences. I had for a good while employed my rather scanty leisure for observation in preparing a catalogue of polar stars which had been or could be employed as standards; had published a portion of the right ascensions reduced to 1885, and was desirous of filling up gaps in observing—time, due to the completion of the original project in certain hours of right ascension.

Originally I intended to obtain trustworthy places of all stars to $7^{m}\cdot5$ inclusive within 10° of the North Pole, and all other stars which had been regularly used as standard polars. The latter class are usually brighter than $7^{m}\cdot5$, and are more numerous than one would imagine; but at Oxford fainter stars had been also used as standard polars, and in some cases by Mr. Carrington and others.

The enlargement of the working list which at once presented itself as desirable was one which should give accurate positions of four to six stars to every four square degrees within 10° of the pole. By using Lœwy's method of tying the zero-points of neighbouring plates together, the number just mentioned will give the zero-points for the centres of the plates, and the scales will be determined by the overlapping portions common to two plates.

In some parts of the sky, as every observer well knows, bright stars are much less numerous than elsewhere, so that these portions require the meridian observation of fainter stars. There are, for example, portions of *Orion*, where the Radcliffe Catalogue for 1890, containing all 7th magnitude stars, furnishes six stars or more to the square degree. In the same region Professor Valentiner has observed all stars down to $8^{m}\cdot0$ between the equator and 8° of south declination; his catalogues will furnish the required number for additional areas, where stars of 7th magnitude are too few. His scale of observation is rather more minute than Mr. Stone's, and his results depend quite uniformly on six observations, part of which are unpublished. Meanwhile the Astronomische Gesellschaft is carrying on its survey, to include all stars to $9^{m}\cdot0$, and all fainter which have been

previously observed by certain specified astronomers; and we thus have, for the region of Schoenfeld's Durchmusterung, almost everywhere materials enough for the photographic zero-points.

This is not quite so in the northern hemisphere. The Astronomische Gesellschaft's survey dates (on the average) twenty years back. In order to avoid the necessity of extrapolating the proper motions up to 1900, it will be necessary to re-observe a sufficient number of stars.

The consideration of the required accuracy at once relieves us of the fear that meridian observation will become a thing of the past. The probable error of a star's position on a photographic plate is not much more than a tenth of a second in either coordinate, if the necessary precautions are taken; and this is very nearly equal to the probable error which M. Lœwy found, to his regret (*Comptes Rendus*, cxvi. 710: April 4, 1893), for the position of the centre of a plate derived from twenty-six stars in four areas. The large probable error is due to extrapolation, or the assumption of zero proper motion. It would be somewhat diminished by using the stars of the Astronomische Gesellschaft, but still more by re-observation.

The following results may be interesting in this connection. In 1892 I prepared a catalogue of 627 stars in declination for the Mexican Boundary Commission. The positions were of course extrapolated, and all the good catalogues I could find were used. If the star was one of Bradley's, the proper motion given by Professor Auwers was usually accurate enough, and could be tested by intermediate observations. If it was only found in Lalande's or Bessel's zones, before it had been observed in a more deliberate way, it was frequently necessary to discard the star, even when it made an excellent companion (in a pair for the zenith telescope) to a well-known star of Bradley's. The stars actually employed gave probable errors in declination, from $\pm 0''{\cdot}1$ up to $\pm 0''{\cdot}5$, as calculated rather rigidly, with a fair allowance for unexpected sources of error. But these were of the 6th magnitude or brighter; and the largest probable errors were due to uncertain proper motion.

The Coast and Geodetic Survey sometimes use declinations of similar stars, when probable errors are larger than this, even up to 1″, because in their work the star can be re-observed, if need be, before the final reduction. This is not usually possible in establishing a boundary.

What, then, is the probable error of a determination by four good observations? I assume that the division errors will be rendered harmless by using the instrument in different positions or shifting the microscopes, or by employing more division lines. The objection that there is too great accumulation of small errors in employing the differential method is one which is rapidly disappearing; and thorough ventilation of observing-rooms and truly central field illumination, with great care on the observer's part, and good instruments, now make much more accurate individual observations possible.

The probable error of one such need not be more than $\pm 0^s.03$ $\pm 0''.4$ with a good instrument; and allowing something for constant error, the mean of four observations need not have a greater probable error than $\pm 0^s.02$ $\pm 0''.25$ if sufficient care is taken.

With six stars to a photographic plate, each determined by two independent instruments with this accuracy, the probable error of the centres would be sensibly less than $\pm 0''.10$ in either coordinate, and the combination with the older observations would be favourable, and still farther diminish the probable errors.

The dangers arising from the use of the differential method need to be minimised by a large catalogue of secondary fundamental stars, and their determination will be facilitated by the latest improvements in instruments and observing. The errors of division of all the single lines or diameters are rarely determined; but it is possible with many instruments to change the circle on the axis. This has been done at Washington regularly, for a quarter of a century, so that the ordinary *Nautical Almanac* stars are quite freed from this source of error. Flexure is more troublesome with large instruments; but the Repsolds have succeeded in nearly getting rid of it by carefully calculated symmetry in their instruments; and the exchange of object-glass and eyepiece, while it may not eliminate flexure entirely, certainly gives two independent flexures, which probably have contrary signs.

The problem of ascertaining primary star-places by direct comparisons with the Sun, and independent determination of refraction flexure, &c., will certainly afford occupation for a number of astronomers for a good many years. But independent primary catalogues are now more numerous and agree better than formerly; and the efforts now being made will doubtless render them far more available for observatory use.

The fact is that the photographic catalogue plates set the standard of meridian observation higher than any former process of astronomy requires. The zero-points of the plates must be very accurately established. This requires the observation of many small stars, with great precision; this again reacts upon the needful accuracy of the many standard stars which are not of first importance; and this again requires that the fundamental brighter stars, which can be well observed by day, shall be fixed with the last degree of care. An accuracy which does not now meet a pretty high standard is but of little use.

In conclusion, I desire to say that Mr. Gill's suggestion for a convention in 1896 seems a good one. If such a convention can be held it would be a benefit, not only to the astronomers of large observatories, who have ample means, but in this country at least to a good many who are limited in their power of effecting large results by scantiness of means, frequently involving many other duties. Practical astronomy is now taught in a good many of our colleges, and those who learn it occasionally accom-

plish some scientific work. But the instructors themselves need to practise the art they are teaching; and are gradually acquiring the instruments, and in some small degree the leisure, which is necessary. It would be a great benefit to them if they could be so brought into contact with better observers that they could measure themselves against them. And a congress as suggested by Mr. Gill would powerfully stimulate the progress of accurate observing in this country. If, however, such a congress cannot be organised, it is to be hoped that the subject of distribution of meridian observation and its arrangement to avoid waste of labour will be thoroughly discussed by the masters of that subject.

The *British Association Catalogue*, now a scarce and costly book, has been of much benefit, and has done some injury. Its convenience made it a good working list; but its incompleteness, even as to naked-eye stars, prevented a good many astronomers from observing such as were fainter than those it included, or had been accidentally omitted, though bright enough. Thus it happens that the existing star catalogues do not yet completely meet even the wants of field astronomers using portable instruments.

The problem of comet observations with equatorials will most readily be solved when the stars near the paths of these bodies have been photographed, and their places can be fixed with great accuracy.

The principle which seems to me the best in choosing objects for meridian observation of the stars is to classify them according to magnitude.

1^m–$4^m{\cdot}0$ Struve's primary stars.
$4^m{\cdot}0$–$6^m{\cdot}5$ Secondary stars, to be regularly and precisely determined.
$6^m{\cdot}6$–$7^m{\cdot}5$ Tertiary stars, to be observed with more regularity than they have been.
$7^m{\cdot}6$–$8^m{\cdot}5$ and $8^m{\cdot}6$ and fainter } When necessary for photographic zero-points and other purposes.

Each class should be observed with greater accuracy and more care than the following, because in general more important; and stars of 6th and brighter magnitudes should be the standards for the determination of telescope.

As, however, these are largely opinions based on an experience narrow in certain directions, I venture to suggest the usefulness of fully discussing the instruments, the methods, the organisation, the resulting accuracy, and the attainable and desirable accuracy of meridian work. The evil to be avoided is the continuance of any such ancient routine methods as hinder the attainment of the precision desirable.

Williamstown, Mass.:
1894 *December* 28.

On the Effect of Atmospheric Dispersion on the position of a Star.

By Professor Arthur A. Rambaut, M.A., Sc.D.

In these days of extreme accuracy in astronomical observations any effect, however small, that will influence the results cannot be overlooked. For this reason, my attention having been recently directed to the necessity of increasing the constant of refraction as determined by Bessel when it is desired to apply it to the correction of photographic measures (v. *Astronomische Nachrichten*, No. 3255), I have been at considerable pains to ascertain how far it may be necessary to take into account the character of the light of a star in computing the refraction by which it is affected in the case of visual observations.

In a paper by Stephen Lee, published in the *Phil. Trans.* of the Royal Society as early as 1815, the effect of the difference in colour of two stars has been in a general way pointed out, and some observations made by him on the planet *Mars* are described. His observations were, however, wanting in the precision necessary to such a delicate research, and led to no very definite numerical results.

His paper, however, seems to have attracted some attention at the time, and was translated by Professor Brandes, of Breslau, for Bode's *Astronomisches Jahrbuch* for the year 1819.

But although it is obvious when pointed out that the constant of refraction applicable to any particular star will depend on the character of its spectrum, I think it has been very generally assumed that the effect of a difference in the light of two stars will, under any circumstances likely to occur in practice, be so small as to be quite insensible. It has hitherto in all cases, so far as I am aware, been taken for granted that the Besselian formulæ for the differential refraction fully correct for this effect, and that any uncertainty which may exist as to the exact value of the coefficient of refraction has no effect on the resulting measures, since the differential is, in general, such a small proportion of the total refraction. This would undoubtedly be true were the coefficient of refraction always the same for both stars, for even if there were a doubt, amounting to as much as one-fiftieth of the whole, it would but rarely make itself felt in differential measures.

It is, however, quite otherwise if the coefficient is to be considered different for two stars in close proximity to one another. For if the coefficient for one of the two stars exceeds that for the other by a certain fraction of its whole amount, the outstanding correction, which the Besselian formulæ fail to take account of, is the same fraction, not of the differential, but of the absolute refraction affecting the star, and this, even at moderate zenith distances, may easily in certain cases become comparable with, or largely exceed, the correction for the

differential refraction. In fact, the refraction for light of a particular wave-length being denoted by the expression

$$\alpha\,(\mathrm{BT})^{\Delta\gamma\lambda}\tan\zeta,$$

or simply $\beta\tan\zeta$, where β is a function of ζ, if the coefficient of $\tan\zeta$ for another star is different, we shall have the refraction in its case denoted by

$$(\beta'+d\beta)\tan\zeta',$$

where β' is the value of β corresponding to the zenith distance ζ', and $d\beta$ the correction for a difference of refrangibility.

Now the first part only of this, namely, $\beta'\tan\zeta'$, is taken account of by Bessel's formulæ. There will thus be the part $d\beta\tan\zeta'$ still outstanding, which will affect the difference between the zenith distances of the two stars by its whole amount.

With the object of ascertaining the order of magnitude to which this outstanding difference can attain I remark that, if μ is the refractive index of air for any particular ray, and if β is the corresponding coefficient of refraction, we have approximately

$$\beta=\frac{\mu^2-1}{c\rho},$$

where ρ is the density of the air and c a constant. Hence for any two particular rays, μ and μ_0, we have

$$\beta-\beta_0=\frac{\mu^2-\mu_0^2}{\mu_0^2-1}\beta_0;$$

or, since μ and μ_0 are both very nearly equal to unity, we may write

$$d\beta=\frac{d\mu}{\mu_0-1}\beta_0.$$

If we imagine two monochromatic stars, both of which are orange, but such that the light of one corresponds to the red end, and that of the other to the green end of the orange, we may put

$$\mu_0-1=0.00029508;\qquad d\mu=0.00000114;$$

and we have

$$\beta_0=57''\cdot682;$$

whence we find

$$d\beta=0''\cdot222,$$

or multiplying by $\tan\zeta$ we get the following corresponding values :—

ζ	$d\beta\tan\zeta$.	ζ	$d\beta\tan\zeta$.
30°	0″·13	60°	0″·39
45	0·22	75	0·83

Of course the light of the stars is not monochromatic, nor does the difference between the brightest parts of their spectra in most cases correspond to as large a value of $d\mu$ as that I have assumed; but the quantities given above show at least that in delicate researches, such as annual parallax or the relative proper motion of stars, the effect of a possible difference in the refrangibility of their light ought not to be overlooked. I would also point out that this effect is not dependent upon the distance apart of two stars, but affects the relative position of two very close stars, quite as much as of two very distant stars; and this might in many cases help to explain a systematic difference depending on hour angle, which seems to affect the position angles of double stars as determined by many observers. For if the two components differed in colour as much as we have supposed above, a relative displacement such as that found in the little table would certainly affect the position angle of a close companion very largely, and might in extreme cases even put it into a different quadrant. And although in general the colours of stars may not differ to the extent I have supposed above, yet occasionally, and especially amongst the binary pairs, we find components so strongly contrasted in colour that some effect such as I have indicated must make itself felt.

It may perhaps be objected that, if the dispersion I refer to is sufficient to affect measures of position, then the image of each star ought to appear in the form of a small spectrum. But this effect does take place to a certain extent at all altitudes, and in the neighbourhood of the horizon becomes quite noticeable. Bouguer, in 1729, was the first to notice this atmospheric dispersion Sir W. Herschel, in 1785, and Stephen Lee, in 1815, tried to measure its amount. Robinson found that the image of *α Lyræ* at its lower culmination at Armagh measured $22''$ in a vertical direction. F. Struve found a similar extension of the image of *α Piscis Australis* at its culmination above the horizon of Dorpat, and concluded that the atmospheric dispersion is about $\frac{1}{100}$th of the refraction, but that the faintness of the extreme colours renders the spectral character of the images inconspicuous at altitudes above 30°. In 1838 Bessel made some heliometer measures of the image of *α Piscis Australis*. These are discussed by Montigny in the *Bulletins de l'Académie de Belgique*, 1867, and he concludes that the observed dimensions of the image agree with those which might have been calculated by means of the indices of refraction.

Even in the case of two stars whose light is intrinsically of the same character, a marked difference of brightness would in all probability affect the measures of their relative position in the same way, if not to the same extent. For in almost all cases measures of precision are made in the field of a telescope which is illuminated by white or yellow light. Now the appearance of a bright star will not be sensibly affected by such an illumination, but if a very faint star is under examination, it is

the bluer rays that will distinguish it from the rest of the illuminated field, and the image will be formed at the place occupied by these rays in the little spectrum into which the light of the star is dispersed by the atmospheric refraction. We should thus expect to find that for the fainter stars a slightly larger coefficient of refraction would be necessary.

With the object of determining whether the difference of colour in so strongly contrasted a pair as the two components of *β Cygni* would make itself felt, I have taken a number of measures of this pair at different zenith distances, which show clearly a systematic difference affecting the distance between them of the sort, and in the direction, that theoretical considerations indicate. The observations were taken under very indifferent circumstances with regard to definition and steadiness, and for the most part on the western side of the meridian, so that the effect of colour is not so distinctly shown as it would be by a comparison of measures made at considerable distances from the zenith on both the eastern and western sides. I have, however, commenced a series of measures of *γ Andromedæ* which when complete will, I hope, be even more conclusive.

The observations were made with the Pistor and Martins micrometer attached to the 12-inch refractor, using a power of 300 in all cases.

If we denote by β the coefficient of refraction corresponding to the principal star, and by $\beta(1+\lambda)$ that corresponding to the companion, the effect of difference of colour is to diminish the zenith distance of the latter by the amount $\lambda\beta \tan \zeta$, or since the variation in β will have quite an insensible effect on $\lambda\beta$, we may write this $x \tan \zeta$.

Hence if d, p are the apparent, and d', p' the true, distance and position of the companion, and if q is the parallactic angle, we have

$$d = d' + x \tan \zeta \cos (p-q)$$

and

$$p = p' - x \tan \zeta \sin (p-q)/3600 \sin d,$$

d, d', and x being expressed in seconds of arc and p, p' in degrees.

The effect of the coefficient of refraction, β, on the two stars has been corrected by means of the ordinary formulæ in which d_0 and p_0 denote the observed values, viz. :

$$d = d_0 + \beta d_0 \{\tan^2 \zeta \cos^2 (p-q) + 1\} = d_0 + \Delta d,$$

and

$$p = p_0 - \beta \{\tan^2 \zeta \sin (p-q) \cos (p-q) + \tan \zeta \sin q \tan \delta\}/3600 = p_0 + \Delta p.$$

By means of these formulæ the following table was computed for Δd and Δp :

Sid. Time. h	Δd. ″	Δp. ′	Sid. Time. h	Δd. ″	Δp. ′
12	+0·009	+1·5	20	+0·011	−0·2
13	·010	1·4	21	·012	0·3
14	·010	1·1	22	·015	0·4
15	·010	0·7	23	·020	0·6
16	·010	0·4	24	·029	1·0
17	·011	+0·2	1	·051	1·7
18	·011	0·0	2	·141	3·6
19	·011	−0·1			

A complete observation consisted of two readings of the parallel followed by three determinations of the position angle, after which four settings for distance were made.

The wires were then reversed, four more settings of the wires in the reversed position were made, followed by three readings of the position angle, and finally two more determinations of the parallel.

When corrected for refraction from the preceding table they become—

No.	Date. 1894.	Sid. Time. h	m	Dist. ″	Position. °	Weight.	Definition.
1	Aug. 3	20	0	34·695	55·185	1	Good at first, but worse towards end.
2	21	21	20	...	54·883	1	Through clouds.
3	Sept. 2	20	35	·403	54·935	½	Most unsteady.
4	2	21	46	...	54·923	1	
5	4	21	24	·564	55·028	1	Definition bad.
6	4	0	13	·756	54·882	1	
7	4	0	55	·662	...	1	
8	4	1	15	·721	...	1	
9	6	18	55	·487	55·315	1½	Splendid.
10	6	23	21	...	55·145	½	
11	6	0	27	·766	...	1	Fair.
12	8	18	53	·711	55·038	½	Poor.
13	8	0	7	...	[55·107]		Definition awful. Stars like balls of wool.
14	13	0	12	·661	55·457	1	Much fog.
15	27	1	26	·972	54·907	1	Bad, but readings fairly accordant.
16	29	20	20	·660	55·008	1	Fair, but unsteady.
17	29	0	34	·822	55·283	1	Fair at first, but disimproved towards end.
18	Oct. 1	20	37	·489	54·987	1	
19	1	0	42	·673	54·967	1	

An examination of the results obtained on September 4, 6, 29, and October 1, when observations at widely different hour angles, but otherwise under similar conditions, were possible,

shows at once a tendency in the distance to increase as the star approaches the western horizon. The measures of position I found exceedingly difficult on most occasions in consequence of the unsteadiness of the images, and they are affected by such large accidental errors as completely mask any systematic law of variation.

The distances give us fifteen equations of the form

$$d' + x \tan \zeta \cos (p - q) = d.$$

Hence, if we put

$$d' = 34''{\cdot}500 + w$$

and take

$$\tan \zeta \cos (p - q)$$

from the following table

Sid. Time. h m	$\tan \zeta \cos (p-q)$.	Sid. Time. h m	$\tan \zeta \cos (p-q)$.
18 26	+0·144	23 26	+1·178
19 26	0·275	0 26	1·643
20 26	0·430	1 26	2·399
21 26	0·619	2 26	3·886
22 26	0·858		

and if we arrange the observations according to the sidereal time at which they were taken, we obtain the equations :

No.			Weight.	Res. I.	Res. II.
12	$w + 0{\cdot}21\,x$	$-0''{\cdot}211 = 0$	½	−0·101	−0·040
9	+0·21	+0·013	1½	+0·113	+0·184
1	+0·37	−0·195	1	−0·080	−0·024
16	+0·42	−0·160	1	−0·041	+0·011
3	+0·47	+0·097	½	+0·220	+0·268
18	+0·47	+0·011	1	+0·134	+0·182
5	+0·62	−0·064	1	+0·073	+0·107
14	+1·55	−0·161	1	+0·058	+0·010
6	+1·55	−0·256	1	−0·037	−0·085
11	+1·68	−0·266	1	−0·036	−0·095
17	+1·79	−0·322	1	−0·082	−0·151
19	+1·84	−0·173	1	+0·071	−0·002
7	+2·02	−0·162	1	+0·098	+0·009
8	+2·25	−0·221	1	+0·060	−0·050
15	+2·40	−0·472	1	−0·178	−0·301

Solving these by the method of least squares, we find

$$w = +0''{\cdot}082 \qquad \text{Weight } 4{\cdot}245$$
$$x = +0{\cdot}088 \qquad \text{,, } 8{\cdot}853$$

and the probable error of a single observation is

$$r = \pm 0''{\cdot}0706.$$

The residuals given by this solution are exhibited in the column headed Res. I.

If we neglect the correction x, and simply take the mean of all the observations with the weights given above, we find

$$w = +0''.171$$

and

$$r = \pm 0''.0922.$$

This solution is inferior to the first for the double reason that it gives a larger probable error of a single observation, and also that the residuals, which will be found in the last column, show a very sharp division into two groups, the positive residuals with one insignificant exception corresponding to the smaller coefficients of x, while the negative residuals with the exception of the first and twelfth observations, both of which were unsatisfactory, are to be found at the end of the table. The residual, too, given by the last equation, amounting to $0''.301$, is scarcely admissible.

That the effect of such a correction is not inconsiderable appears from a comparison of the two values of w given by the two solutions which lead respectively to the two values of the distance $34''.582$ and $34''.671$.

From the equation

$$d\beta = \frac{d\mu}{\mu_0 - 1}\beta_0,$$

or

$$d\mu = \frac{d\beta}{\beta_0}(\mu_0 - 1),$$

$d\beta$ being equal to x, we find

$$d\mu = \frac{0''.088}{57''.682} \times 0.00029508 = 0.00000045;$$

or a difference in the refrangibility of the light of the stars less than one-half (0·4 times) the difference between the D and E lines of the spectrum would account for the whole phenomenon.

In this case perhaps it may be a matter of surprise that the difference should not prove to be greater than it actually does, the principal star being of a golden yellow, and the companion of a distinctly blue, colour. But even the blue companion contains a great deal of orange and yellow light, which in consequence of the brightness of the star will go far towards diminishing the effect at present under consideration.

The observations of γ *Andromedæ*, so far as they have at present proceeded, indicate that in the case of this star, too, there is a systematic difference of the same sort affecting the measures. The following table contains the measures of the distance, corrected for the ordinary differential refraction and

arranged in order of the sidereal time at which they were made, with the corresponding values of tan $\zeta \cos (p-q)$:

No.	Date.	Sid. Time.	Dist.	tan $\zeta \cos (p-q)$.	Definition.
		h m	″		
1	Sept. 15	18 56	10·143	−0·477	Very good at first, but disimproving.
2	27	19 54	·244	·495	Unsteady throughout.
3	8	20 2	·178	·490	Fair.
4	Oct. 2	20 5	[·028]	·490	Very bad. Observations very difficult and tedious.
5	Sept. 6	22 3	·190	·363	Poor. Images unsteady.
6	4	22 44	·148	·296	Middling.
7	8	23 11	·253	·255	Bad. Most unsteady.
8	Oct. 1	23 15	·254	·244	Fair, but a little unsteady.
9	Sept. 27	23 47	·204	·177	Exquisite, but images a little unsteady.
10	Oct. 21	0 45	·332	−0·068	Very good.

It will be noticed that in this series, with the exception of the second observation, in which the star images were most unsteady, the distance tends to increase as the star approaches the meridian. This is what we should expect from the values of tan $\zeta \cos (p-q)$. In the case of β *Cygni*, on the contrary, the larger measures corresponded to larger hour angles, the observations being made on the western side of the meridian. Unfavourable weather has, however, hitherto prevented me from getting measures of γ *Andromedæ* in this position.

It is in parallax measures that we should expect this effect to become most conspicuous, as we are in this class of work nearly always engaged in measuring the position of a fairly bright star with regard to fainter ones in its neighbourhood, and the hour angle of the star at the time of observation will, in general, range through 90° or more on each side of the meridian. Accordingly, while the observations of β *Cygni* and γ *Andromedæ* were in progress I examined the measures of 61 *Cygni*, made at this observatory by Sir Robert Ball in the years 1877 and 1878. I have selected this series rather than the later and more complete series published in the Fifth Part of *The Dunsink Observations and Researches*, in part deliberately and partly in consequence of a misconception. In the first place the very shortness of the first series, leading as it did to practically the same value of the parallax as the longer one, recommended it to me for a first investigation, and in the second place I was under the impression that the longer series consisted of measures, not of the difference of declination, but of the distance of the two stars, which would

have necessitated much longer work in computing the factors for x.

In the Third Part of *The Dunsink Observations and Researches* Sir Robert Ball gives thirty-six measures of the difference of declination between the preceding component of 61 *Cygni* and a faint (9·5 mag.) star north following, from which he deduces a parallax of 0″·465.

In the case of measures of the difference of declination we must put $p=0$, whence we find the effect on such measures of a difference of refrangibility in the light of two stars to be

$$x \tan \zeta \operatorname{ccs} q.$$

But

$$\tan \zeta \cos q = \cot (\delta + m),$$

where m is the quantity which Bessel denotes by N. We thus find for the outstanding part of the refraction in declination the expression

$$x \cot (\delta + m).$$

In Sir Robert Ball's treatment of the equations of condition furnished by the observations he introduces a correction

$$[9{\cdot}92224]\ \kappa \sin (58^\circ\ 17' + \odot),$$

for a possible difference (κ) in the constant of aberration corresponding to the two stars. But as there appears to be no physical reason for the existence of such a difference, I have omitted it in the solution which follows. It will therefore be understood that I have not introduced an additional unknown quantity into the equations, which would, of course, help to diminish the residuals, and therefore the probable error of an observation, but have substituted, in place of a correction which is not likely to have any real physical meaning, another quantity which must exist, whether it is large enough to be sensible or not.

In five of the observations the sidereal time is not published, but I have in two cases been able to supplement this datum from the original observing books. In three cases, however, this quantity does not appear to have been observed—namely, in the tenth, seventeenth, and thirtieth observations—and I have accordingly been obliged to omit them. All the other observations have been included with the weights assigned by Sir Robert Ball. I thus obtain the following equations of condition in which the mean difference in declination is taken equal to $67''{\cdot}150+w$; the proper motion is assumed to be $3''{\cdot}232+y$, $d\delta$ is denoted by x and π (the parallax) by z:

No.	Equations of Condition.				Weight.	Residuals.
				"		"
1	$w + 0{\cdot}276\,x$	$-0{\cdot}496\,y$	$-0{\cdot}801\,z$	$+0{\cdot}271 = 0$	...	$-0{\cdot}044$
2	$+0{\cdot}401$	$-0{\cdot}489$	$-0{\cdot}814$	$+0{\cdot}251$	...	$-0{\cdot}063$
3	$+0{\cdot}306$	$-0{\cdot}453$	$-0{\cdot}847$	$+0{\cdot}411$	...	$+0{\cdot}079$
4	$+0{\cdot}369$	$-0{\cdot}445$	$-0{\cdot}849$	$+0{\cdot}223$	$\frac{1}{2}$	$-0{\cdot}108$
5	$+0{\cdot}346$	$-0{\cdot}440$	$-0{\cdot}849$	$+0{\cdot}248$	...	$-0{\cdot}084$
6	$+0{\cdot}276$	$-0{\cdot}409$	$-0{\cdot}833$	$+0{\cdot}352$	...	$+0{\cdot}023$
7	$+0{\cdot}330$	$-0{\cdot}388$	$-0{\cdot}803$	$+0{\cdot}283$	...	$-0{\cdot}033$
8	$+0{\cdot}279$	$-0{\cdot}335$	$-0{\cdot}674$	$+0{\cdot}191$	...	$-0{\cdot}075$
9	$+0{\cdot}279$	$-0{\cdot}327$	$-0{\cdot}648$	$+0{\cdot}455$	...	$+0{\cdot}199$
10	[...]	$-0{\cdot}278$	$-0{\cdot}452$	$+0{\cdot}208$	...	[...]
11	$+0{\cdot}789$	$-0{\cdot}261$	$-0{\cdot}377$	$+0{\cdot}249$	...	$+0{\cdot}122$
12	$+0{\cdot}583$	$-0{\cdot}251$	$-0{\cdot}324$	$+0{\cdot}262$	...	$+0{\cdot}148$
13	$+0{\cdot}901$	$-0{\cdot}231$	$-0{\cdot}229$	$-0{\cdot}154$	...	$-0{\cdot}217$
14	$+0{\cdot}644$	$-0{\cdot}209$	$-0{\cdot}116$	$+0{\cdot}137$	$\frac{1}{2}$	$+0{\cdot}108$
15	$+0{\cdot}327$	$-0{\cdot}191$	$-0{\cdot}018$	$-0{\cdot}045$	...	$-0{\cdot}049$
16	$+0{\cdot}710$	$-0{\cdot}185$	$+0{\cdot}014$	$+0{\cdot}129$	...	$+0{\cdot}154$
17	[...]	$-0{\cdot}174$	$+0{\cdot}070$	$-0{\cdot}219$	...	[...]
18	$+0{\cdot}567$	$-0{\cdot}163$	$+0{\cdot}128$	$-0{\cdot}150$	...	$-0{\cdot}086$
19	$+0{\cdot}609$	$-0{\cdot}133$	$+0{\cdot}282$	$-0{\cdot}194$	...	$-0{\cdot}067$
20	[...]	$-0{\cdot}048$	$+0{\cdot}633$	$-0{\cdot}551$	...	[...]
21	$+0{\cdot}918$	$-0{\cdot}046$	$+0{\cdot}641$	$-0{\cdot}324$	...	$-0{\cdot}041$
22	$+1{\cdot}791$	$-0{\cdot}040$	$+0{\cdot}669$	$-0{\cdot}332$	...	$0{\cdot}000$
23	$+1{\cdot}054$	$-0{\cdot}035$	$+0{\cdot}684$	$-0{\cdot}176$	...	$+0{\cdot}140$
24	$+1{\cdot}726$	$-0{\cdot}007$	$+0{\cdot}755$	$-0{\cdot}200$	$\frac{1}{2}$	$+0{\cdot}163$
25	$+1{\cdot}449$	$-0{\cdot}004$	$+0{\cdot}760$	$-0{\cdot}403$	...	$-0{\cdot}050$
26	$+1{\cdot}956$	$+0{\cdot}083$	$+0{\cdot}811$	$-0{\cdot}509$	...	$-0{\cdot}115$
27	$+0{\cdot}874$	$+0{\cdot}226$	$+0{\cdot}384$	$-0{\cdot}123$	$\frac{1}{2}$	$+0{\cdot}051$
28	$+1{\cdot}124$	$+0{\cdot}226$	$+0{\cdot}384$	$-0{\cdot}283$	...	$-0{\cdot}098$
29	$+0{\cdot}874$	$+0{\cdot}245$	$+0{\cdot}292$	$-0{\cdot}102$	$\frac{1}{2}$	$+0{\cdot}035$
30	$+0{\cdot}652$	$+0{\cdot}248$	$+0{\cdot}278$	$+0{\cdot}149$	$\frac{1}{2}$	$+0{\cdot}270$
31	$+0{\cdot}567$	$+0{\cdot}292$	$+0{\cdot}055$	$-0{\cdot}074$	...	$-0{\cdot}046$
32	$+0{\cdot}652$	$+0{\cdot}311$	$-0{\cdot}044$	$-0{\cdot}011$	...	$-0{\cdot}019$
33	$+0{\cdot}616$	$+0{\cdot}319$	$-0{\cdot}087$	$+0{\cdot}298$	$\frac{1}{2}$	$+0{\cdot}271$
34	$+0{\cdot}616$	$+0{\cdot}377$	$-0{\cdot}374$	$+0{\cdot}299$	$\frac{1}{2}$	$+0{\cdot}156$
35	$+0{\cdot}485$	$+0{\cdot}404$	$-0{\cdot}495$	$+0{\cdot}462$	...	$+0{\cdot}264$
36	$+0{\cdot}532$	$+0{\cdot}415$	$-0{\cdot}540$	$-0{\cdot}191$	...	$-0{\cdot}405$

Solving these equations by the method of least squares, and taking account of the weights in the second last column, we find the following normal equations :

$+29{\cdot}00\,w$	$+20{\cdot}69\,x$	$-2{\cdot}74\,y$	$-3{\cdot}73\,z$	$+0{\cdot}959=0$
$+20{\cdot}69$	$+21{\cdot}60$	$-0{\cdot}58$	$+3{\cdot}40$	$-2{\cdot}015=0$
$-\ 2{\cdot}74$	$-\ 0{\cdot}58$	$+2\ 66$	$+2{\cdot}68$	$-1{\cdot}043=0$
$-\ 3{\cdot}73$	$+\ 3{\cdot}40$	$+2{\cdot}68$	$+9{\cdot}48$	$-3{\cdot}949=0$

from which we deduce

	Weight.
$w=-0''{\cdot}014\pm0''{\cdot}050$	3·72
$x=+0{\cdot}043\pm0{\cdot}058$	2·74
$y=-0{\cdot}016\pm0{\cdot}072$	1·79
$z=+0{\cdot}400\pm0{\cdot}055$	3 05

and for the probable error of a single observation,

$$r=\pm0''{\cdot}0956.$$

Comparing this with Sir Robert Ball's solution, namely,

	Weight.
$w=+0''{\cdot}027\pm0''{\cdot}021$	27·28
$y=-0{\cdot}094\pm0{\cdot}122$	0·8145
$z=+0{\cdot}465\pm0{\cdot}050$	4·887
$\kappa=+0{\cdot}033\pm0{\cdot}049$	4·973

and

$$r=\pm0''\ 1099,$$

we see that it represents the observations better, as is shown both by the smaller value of r and by the fact that the theoretical weights of the various quantities are much more nearly equal in it than in Sir Robert Ball's solution.

Whilst engaged in this work I happened to call to mind two cases in which observers of deservedly high reputation were led to suspect the existence of a systematic error depending on the hour angle of observation.

In the Second Part of *The Dunsink Observations and Researches*, when discussing the measures of the position angle of the 9th magnitude companion to 85 *Pegasi*, Dr. Brünnow says : "In order to see whether these values exhibit any dependence on the position in which the stars were observed with regard to the vertical circle I have computed for every observation the angle $p'-\eta=N$, where η is the parallactic angle ; and I give in the following table the values of p arranged according to the values of this angle :—

* * * * * * *

As the values in this table seem to indicate a maximum when N is in the neighbourhood of 90°—that is, when the line joining the stars is in a horizontal position—I have assumed the correction which must be applied to the observed angles of position, when the angle with the vertical line is

$$90° \mp N$$

to be of the form

$$+\frac{\varpi}{\Delta}(1-\sin N),$$

and I have introduced such a term in the equations of condition."

It is scarcely to be wondered at that, with an expression so different in form from the true one (if the systematic difference he suspected be due to unequal refrangibility), he should not have found this term add anything to the accuracy of the results.

Beyond, however, noticing in a general way that the value of p seems, from Brünnow's table, to increase with ζ quite as much as with N, I have not further pursued the subject at present, my attention having been wholly occupied with the series of measures of the parallax of *α Centauri* made by Drs. Gill and Elkin at the Cape of Good Hope in the years 1881–82–83.

In the account of these observations, which is published in the *Memoirs of the Royal Astronomical Society*, vol. xlviii., Dr. Gill remarks on page 17: "I soon obtained unquestionable evidence of the existence of considerable systematic error depending on the hour angle of observation." He therefore divides his observations into four groups, thus:

(i.) Observations made at great hour angles east, denoted thus ⏐●⏐

(ii.) Observations made at small hour angles east, denoted thus —●—

(iii.) Observations made at small hour angles west, denoted thus ⏐○⏐

(iv.) Observations made at great hour angles west, denotes thus —○—

And he remarks further, on page 23: "A glance at the diagram, at the times when nearly simultaneous observations were made east and west of the meridian will show that, as a rule, the greatest values of $\alpha-\beta+\Delta D$ occur with observations marked ⏐●⏐, and the smallest with those marked ⏐○⏐: that is, when the corresponding values of $p-q$ differ about 180°; and that the observations marked —●— and —○— occupy intermediate positions.

"It is also clear tha any discussion in which these systematic

errors are not taken into account will give much too large a value of the parallax.

"Beyond these general conclusions it is not easy to go without a more formal discussion; nor without such discussion is it easy to decide whether the systematic corrections are a function of $(p-q)$, or whether they depend entirely on the direction of measurement with respect to the line joining the observer's eyes."

To account for this systematic difference in his first and longest series of observations, Dr. Gill introduces four unknown quantities, $x_{,}$, $x_{,,}$, $x_{,,,}$, $x_{,,,,}$, corresponding to the various positions, ●, —●—, ○, and —○— respectively. Introducing also the quantities, y depending on the time, y' on the square of the time, and z equal to 1·881 π (π being the parallax), he finds the following solution:

	R	R	Weight.
$x_{,}$	= +0·0178	± 0·0022	17·2
$x_{,,}$	= −0·0003	± 0·0030	9·5
$x_{,,,}$	= −0·0214	± 0·0018	24·7
$x_{,,,,}$	= +0·0093	± 0·0029	9·7
y	= −0·0026	± 0·0037	6·2
y'	= −0·0002	± 0·0032	8·2
z	= +0·1092	± 0·0019	22·3

This solution makes the probable error of a single observation of weight unity equal to

$$\overset{R}{r} = \pm 0{\cdot}00918 = \pm 0''{\cdot}1181,$$

and the parallax

$$\pi = 0''{\cdot}747 \pm 0''{\cdot}0133,$$

which value of the parallax Dr. Gill takes as the definitive result to be obtained from this series of observations.

The systematic differences for which Dr. Gill found it necessary to correct in this empirical manner seem to me to be exactly such as we should expect to arise from a small difference of refrangibility in the light of the stars under consideration. I have accordingly examined this series of measures, and the three which follow it in the same memoir, with a view to establishing the existence of such a difference.

In each of the four series of observations of this star the method of observation was the same. The distance of α_2 *Centauri* was measured with the heliometer from two comparison stars situated nearly symmetrically at opposite sides of it, in each series a different pair of comparison stars being employed.

Denoting, then, by

S_0, the mean sum of the distances (in the first series = 536·0510 R);

S, any particular sum of the distances;

D_0, the mean difference of the distances (= 60·000 R);

D, any particular observed difference of the distances;

ΔD, the correction to be applied to D to reduce to normal scale value;

Dr. Gill takes

$$\Delta D = (S_0 - S) \times \frac{D}{S},$$

or practically

$$\Delta D = \frac{D_0}{S_0}(S_0 - S) = 0{\cdot}112\,(S_0 - S).$$

Now, if α be the corrected distance as found by Dr. Gill from the first comparison star, β the corrected distance from the second, and k_1, k_2, k the values of the constant of refraction, which are applicable to the two comparison stars and to α *Centauri* respectively, then the true distances are

$$\alpha' = \alpha - (k_1 - k) \tan \zeta \cos (p_1 - q),$$

and

$$\beta' = \beta - (k_2 - k) \tan \zeta \cos (p_2 - q).$$

As the position angles of the comparison stars in each case differ very nearly by 180°, we may without sensible error put

$$p_1 = 180^\circ + p_2;$$

and we obtain

$$\alpha' = \alpha - (k_1 - k) \tan \zeta \cos (p - q),$$
$$\beta' = \beta + (k_2 - k) \tan \zeta \cos (p - q);$$
$$\therefore S' = S - (k_1 - k_2) \tan \zeta \cos (p - q);$$

and

$$D' = D - (k_1 + k_2 - 2k) \tan \zeta \cos (p - q);$$

and since

$$\Delta D' = (S_0 - S') \times \frac{D'}{S'},$$

it is easy to show that, to the same degree of approximation as before,

$$\alpha' - \beta' + \Delta D' = \alpha - \beta + \Delta D - \frac{S_0}{S}\left\{(k_1 + k_2 - 2k) - (k_1 - k_2)\frac{D_0}{S_0}\right\} \tan \zeta \cos (p - q),$$

or simply

$$\alpha' - \beta' + \Delta D' = \alpha - \beta + \Delta D - x \tan \zeta \cos (p - q).$$

Hence if w is a correction to the assumed difference of the distances D_0; y the effect of proper motion on D_0; and z equal to

1·881 π we find (*cf.* Gill and Elkin's memoir) from each observation an equation of the form

$$w + \tan\zeta\cos(p-q)\,.\,x + ty + \mathrm{R}\,.\,\cos(\odot - 347^{\circ}{\cdot}3)\,z = \mathrm{D} - \mathrm{D}_c.$$

We are thus led to a series of equations of condition for which the weights apportioned by Dr. Gill have been retained. Equations 8, 15, 16, 28, 29, 41, 48, 65, 66, 77, and 89 have been omitted from the solution for reasons given in Dr. Gill's memoir. Equations 16, 28, 29, 48, and 89 might indeed have been included in this investigation, as the reason which led Dr. Gill to reject them—namely, uncertainty as to the position of the observer's head—does not apply in this case, and the smallness of the residuals of all but the last of them shows that the results would not have been sensibly altered if they had been included. I have, however, rejected these equations in what follows so as to make my result more strictly comparable with Dr. Gill's, depending as it does on the very same material.

I have taken the values of $\tan\zeta\cos(p-q)$ to only two decimal places because each observation extended over a considerable time, and consequently the exact sidereal time to which it corresponds does not admit of being stated with any very high degree of precision, and it would have added very considerably to the labour of computing without adding anything to the real accuracy of the correction if I had attempted to include the third decimal.

From these equations (omitted here for economy of space) * we obtain the following normals :

$$\begin{aligned}
&+86{\cdot}50w - 10{\cdot}40x + 31{\cdot}35y + 9{\cdot}98z - 0{\cdot}75 = 0\\
&-10{\cdot}40 + 58{\cdot}26 + 0{\cdot}09 + 32{\cdot}87 - 4{\cdot}19 = 0\\
&+31{\cdot}35 + 0{\cdot}09 + 36{\cdot}56 + 14{\cdot}95 - 1{\cdot}42 = 0\\
&+9\,98 + 32{\cdot}87 + 14{\cdot}95 + 48{\cdot}42 - 5{\cdot}65 = 0
\end{aligned}$$

Solving these we find

	R	R	Weight.
$w =$	$-0{\cdot}0011$	$\pm 0{\cdot}0017$	57·5
$x =$	$+0{\cdot}0074$	$\pm 0{\cdot}0023$	31·2
$y =$	$-0{\cdot}0068$	$\pm 0{\cdot}0028$	21·9
$z =$	$+0{\cdot}1140$	$\pm 0{\cdot}0027$	23·6

whence

$$\pi = 0''780 \pm 0''018.$$

The probable error of a single observation comes out somewhat greater than that found by Dr. Gill, viz.—

$$r = \pm 0{\cdot}01311 = \pm 0''1686;$$

but this is hardly to be wondered at considering that there are

* The factors of x and the residuals will be found on p. 144. The other terms will be found in Dr. Gill's memoir.

in his solution no less than seven unknown quantities amongst which the errors are distributed. We see again, however, that, as in the case of 61 *Cygni*, the introduction of the quantity x tends to equalise the weights with which the various quantities are deduced, and in this case, while the probable error of z is only increased by less than one-half its amount, that of y is diminished in about the same proportion, and that of w is smaller than the probable error of any one of the four corresponding quantities which Dr. Gill employs. The high theoretical weight, too, attached to x, which is greater than that of either y or z, would seem to show that it represents a real systematic error affecting the measures.

With regard to the difference in refrangibility to which this value of x would correspond, since

$$\overset{R}{I} = 12''\cdot865,$$

we find that

$$x = 0''\cdot0952,$$

or about double that found above in the case of 61 *Cygni*, and a trifle greater than that found for β *Cygni*.

Second Series.—Gill.—This second series of measures is in many respects much less satisfactory than the former. It was undertaken as a check on the first and principal series, employing a different pair of comparison stars, and contains only 46 observations in all, which are mostly confined to the epochs of the maxima and minima of parallax. "But," Dr. Gill remarks, "as the observations near the maximum of parallax were necessarily made east of the meridian, and those near the minimum of parallax west of it, some connecting link between observations made in these two conditions was desirable in order to determine whether the deduced parallax is affected by possible systematic error depending on the hour angle of observation.

"Accordingly observations were made in May and June 1883—in the evening east of the meridian, and in the morning west of it—at hour angles similar with those at which the observations near the maximum and minimum of parallax were made."

In this series Dr. Gill introduces only two terms, x_E and x_W, corresponding to observations made east and west of the meridian respectively, but still retains the quantity y' depending on the square of the time. He has evidently been at great pains to find a satisfactory solution, and obtains several, of which none are quite unexceptionable.

What appears the best of these is obtained by making $x_E = x_W$, and rejecting (by Pierce's Criterion) equations 1 and 31; but this, as Dr. Gill points out, gives such a large value of y' as cannot be reconciled with the results of meridian observations, nor with an orbit representing the heliometer observations of α *Centauri* as a double star.

The solution gives

	R	R	Weight
$x^B = x_W =$	$+0\cdot0047$	$\pm 0\cdot0021$	17·27
$y =$	$-0\cdot0217$	$\pm 0\cdot0053$	2·66
$y' =$	$+0\cdot0165$	$\pm 0\cdot0041$	4·37
$z =$	$+0\cdot1144$	$\pm 0\cdot0018$	23·37

whence

$$\pi = 0''\cdot768 \pm 0''\cdot012 ;$$

also

$$r = \pm 0\cdot00865 = \pm 0''\cdot111.$$

Treating this series in the same way as the last, and including all the observations except those which Dr. Gill rejected for *a priori* reasons—namely, Nos. 5, 8, 13, 18, and 22—and giving with him half weight to Nos. 32 and 35, we find the resulting normal equations :—

$+40\cdot00\,w$	$+\ 0\cdot03\,x$	$+27\cdot37\,y$	$-\ 9\cdot29\,z$	$+0\cdot866 = 0$
$+\ 0\cdot03$	$+30\cdot91$	$-\ 2\cdot80$	$-23\cdot65$	$+2\cdot590 = 0$
$+27\cdot37$	$-\ 2\cdot80$	$+37\cdot31$	$-\ 6\cdot66$	$+0\cdot768 = 0$
$-\ 9\cdot29$	$-23\cdot65$	$-\ 6\cdot66$	$+30\cdot12$	$-3\cdot224 = 0$

From which we obtain

	R	R	Weight
$w =$	$+0\cdot0082$	$\pm 0\cdot0028$	19·01
$x =$	$-0\cdot0055$	$\pm 0\cdot0038$	10·41
$y =$	$-0\cdot0086$	$\pm 0\cdot0029$	17·71
$z =$	$+0\cdot1034$	$\pm 0\cdot0040$	9·55

Hence

$$\pi = 0''\cdot694 \pm 0''\cdot028 ;$$

also

$$r = \pm 0\cdot0121 = \pm 0''\cdot1557.$$

The residuals obtained from this solution * are very similar to those found by Dr. Gill, and though the value of r is slightly larger than he finds in his final solution, this has the advantage of being free from an inadmissible value of y', and also, as in the previous cases, brings the weights of the various quantities much closer together, that of x exceeding the corresponding quantity for z.

With regard to the negative sign found for x, it should be remarked that in these observations a wire gauze screen was used to reduce α_2 *Centauri* to about the same magnitude as the two comparison stars employed at the time, and that whereas in the first series of each observer, α_2 *Centauri* thus reduced seemed slightly brighter than the mean of the comparison stars, in this case it was otherwise, the principal star appearing slightly fainter than the mean of the two. On the other hand, in Dr. Elkin's

* See p. 144.

second series the screen had the effect of reducing α_2 *Centauri* to about the brightness of a star of magnitude $8\frac{1}{4}$, while the comparison stars were each of the eighth magnitude, and in that case I have found a positive value of x. But it is extremely unlikely that such minute differences of brightness could have any sensible effect on the measures. It will be seen, however, from the expression for x on p. 136 that this quantity is not necessarily positive; for if the light of the two comparison stars differs in refrangibility considerably more than their mean does from that of α_2 *Centauri*, or if

$$(k_1 - k_2)\frac{D_0}{S_0}$$

is greater than

$$(k_1 + k_2 - 2k),$$

we should have a negative value for x.

It would be interesting to know whether any difference in the colour of these comparison stars can be detected by the eye, or whether any peculiarity is exhibited in the spectrum of either.

We have next to consider the measures of Dr. Elkin, made at the same time, with the same instrument and following the same method

First Series.—Elkin.—This consists of ninety-two observations in which a third pair of comparison stars was employed, whose position with regard to α *Centauri* as well as all information necessary for a complete examination of the results will be found in the original memoir.

This series gives very different values of the parallax (ranging from $0''\cdot650$ to $0''\cdot815$) according to the method of solution.

In one of these Dr. Elkin is driven to the use of five empirical corrections x_W, x_{MW}, x_M, x_{EM}, x_E depending on the hour angle of observation, while in another he solves for eight unknowns, which, as might have been expected, has the effect of reducing the probable error a good deal.

Equations of condition, formed just as in the previous cases, lead to the following normal equations, in which $z = 1\cdot580\,\pi$:

$+87\cdot00\,w$	$+\ 5\cdot91\,x$	$-15\cdot64\,y$	$+17\cdot59\,z$	$+0\cdot145=0$
$+\ 5\cdot91$	$+27\cdot82$	$+\ 0\cdot65$	$-24\cdot02$	$+1\cdot762=0$
$-15\cdot64$	$+\ 0\cdot65$	$+16\cdot19$	$+\ 0\cdot39$	$-0\cdot397=0$
$+17\cdot59$	$-24\cdot02$	$+\ 0\cdot39$	$+52\cdot15$	$-3\,872=0$

whence we obtain

	R	R	Weight
$w =$	$-0\cdot0208$	$\pm 0\cdot0024$	$52\cdot56$
$x =$	$+0\cdot0186$	$\pm 0\cdot0048$	$13\cdot37$
$y =$	$+0\cdot0015$	$\pm 0\cdot0050$	$12\cdot24$
$z =$	$+0\cdot0898$	$\pm 0\cdot0036$	$23\cdot42$
$\pi =$	$0''\cdot732$	$\pm 0''\cdot032$	

and for the probable error of a single observation,

$$r = \pm 0^{s}.0175 = \pm 0''.225.$$

A comparison of the residuals* found by the substitution of these values in the equations of condition with those obtained by Dr. Elkin in his first solution, to which he attaches no weight in deducing his final result, shows that in one respect there is apparently little improvement, namely, in the decided change of sign of the residuals which occurs between the observations 53 and 54 at the point where the observations change from one side of the meridian to the other. On the other hand, there is not the same systematic dependence on hour angle towards the end of the series (where observations, both east and west of the meridian, were obtained) which Dr. Elkin's solution very clearly exhibits.

It would therefore seem that, whatever this systematic error may be due to, when the correction for the dispersion is introduced its effect seems to be confined to bringing about the change of sign in the residuals which takes place about the end of October at the fifty-third equation of condition. Now in the observations taken about this date, the Sun and *α Centauri* were, comparatively speaking, close to one another—almost on the same hour circle—and the star was about 20° above the horizon, while the Sun was only 10° or 12° below it. In fact, these observations were made at the greatest zenith distances of any in the whole four series. Under these circumstances they must have been made in a bright twilight sky, and the contrast made by the light of the stars with the illuminated field must have been very different from what it was at other times, when the stars appeared on a background illuminated only by artificial light.

Under these circumstances it would probably reduce the residuals considerably if we introduced a special correction x, to be applied to all observations made in a twilight sky—a step which would still leave the number of our unknown quantities three less than those employed by Dr. Elkin—but as my object at present is, not to improve on the value of the parallax deduced by Dr. Elkin, but to examine the effect which atmospheric dispersion may have on such measures, I have not done so.

I merely remark that the value of the parallax found in a direct way, without any empirical corrections, agrees very closely with the result which Dr. Elkin is finally led to adopt, and is almost exactly equal to the mean of the values found in the same manner from Dr. Gill's two series of observations.

Second Series.—Elkin.—Dr. Elkin's second series of measures of *α Centauri* is similar to that of Dr. Gill, consisting of observations made about the epochs of maximum and minimum parallax with a group made east and west of the meridian to free this series from systematic errors, such as had been found to exist in the others.

* See p. 145.

These observations furnish fifty equations of condition, of which all but one (No. 24) are employed in the solution, and this one is rejected on account of the fact that the measures were made immediately after the opening of the dome. The observations show a very decided difference depending on the side of the meridian on which they were made. Dr. Elkin is therefore led to introduce the two quantities x_E and x_W, which are applicable to observations made on the eastern and western sides of the meridian respectively, and obtains the following solution when the observations are all given equal weights :

$$\begin{aligned} x_E &= -0''.0231 \pm 0''.0048 \quad \text{R} \quad \text{R} \\ x_W &= +0''.0201 \pm 0''.0048 \\ y &= +0''.0261 \pm 0''.0037 \\ z &= +0''.1033 \pm 0''.0047 \end{aligned}$$

in which

$$z = 1.920\pi,$$

whence he finds

$$\pi = 0''.672 \pm 0''.031 ;$$

also

$$r = \pm 0''.207.$$

This result he afterwards modifies slightly by assigning various weights to the observations according to the character of the images at the time, and finally deduces

$$\pi = 0''.676 \pm 0''.027$$

as the definitive result of the series.

If we treat these observations as we did the three previous series, we obtain fifty equations of condition ; and considering all the observations, with the exception of No. 24, as of equal weight we obtain the normal equations

$+49.00\,w$	$+2.73\,x$	$+24.70\,y$	$+2.94\,z$	$-0.895 = 0$
$+2.73$	$+60.95$	-1.03	-36.54	$+2.781 = 0$
$+24.70$	-1.03	$+32.60$	$+7.15$	$-1.512 = 0$
$+2.94$	-36.54	$+7.15$	$+33.19$	$-2.931 = 0$

Hence we find

		Weight.
	R R	
$w = -0''.0018 \pm 0''.0031$		30.07
$x = +0''.0132 \pm 0''.0039$		19.20
$y = +0''.0269 \pm 0''.0040$		18.42
$z = +0''.0972 \pm 0''.0054$		9.97
$\pi = +0''.651 \pm 0''.036$		

and

$$r = \pm 0''.220$$

The close agreement which a comparison of the residuals* afforded by this solution with those found by Dr. Elkin exhibits would seem to show unquestionably that the systematic error, which Dr. Elkin corrects for by the empirical quantities x_s and x_w, is due to a difference in the mean refrangibility of the light of the stars such as I have supposed to exist.

It appears to me that the result of all these observations—my own observations of β *Cygni* and of γ *Andromedæ*, those by Sir Robert Ball of 61 *Cygni*, and the splendid series of heliometer measures of α *Centauri* by Drs. Gill and Elkin—all point in the same direction, and show that small differences in the mean refrangibility of the light of stars may make themselves felt in precise measurements of their position. And whatever value may be assigned to the particular solutions which I have found for the four series of observations made at the Cape of Good Hope, and whether it be thought that the correction I have introduced accounts fully for the systematic error depending on hour angle which runs through them all, and that the still outstanding quantities should be attributed to the accidental errors inseparable from observations of such delicacy and difficulty (as I believe to be the case in both of Dr. Gill's and in Dr. Elkin's second series), or that the observations are further affected by a systematic error, possibly of a subjective character (as would seem to be the case in Dr. Elkin's first series), I think I have shown at least that in parallax measures a term ought to be introduced into the equations of condition of the form

$$\lambda\beta \tan \zeta \cos (p-q)$$

where results of the highest precision are aimed at.

In conclusion I may remark that although the introduction of such a term has somewhat altered the individual results from those given in the original memoir, yet its effect on the final value of the parallax of α *Centauri* is less than the one-hundredth part of a second. For if we take the mean of the four different values obtained by me with the weights attributed to the corresponding quantities by Drs. Gill and Elkin, we find

$$\pi = 0''{\cdot}743$$

as compared with the value

$$\pi = 0''{\cdot}752$$

obtained by those distinguished astronomers.

* See p. 145.

First Series—Gill.

No.	tan ζ cos (p−q).	Res. R
1	+0·04	+0·004
2	+0·18	+ ·017
3	−0·49	+ ·028
4	−0·38	+ ·013
5	−0·04	+ ·019
6	−0·59	+ ·019
7	−0·04	+ ·008
9	−0·39	+ ·016
10	−0·19	+ ·007
11	−0·63	+ ·003
12	−0·84	+ ·001
13	−0·56	− ·007
14	−0·75	+ ·028
17	−1·20	− ·036
18	−2·39	− ·040
19	−1·27	− ·008
20	−1·62	+ ·015
21	−1·83	− ·028
22	+0·49	+ ·012
23	+0·64	+ ·005
24	+0·66	+ ·009
25	+0·69	− ·006
26	+0·71	+ ·004
27	+0·67	+ ·003
30	+0·65	− ·017
31	+0·60	+ ·015
32	+0·68	− ·017
33	+0·65	+ ·001
34	+0·70	+ ·003
35	+0·70	− ·011
36	+0·57	+ ·016
37	+0·67	− ·013
38	+0·70	·000
39	+0·71	− ·011
40	+0·69	+ ·010
42	+0·08	− ·005
43	+0·66	+ ·011
44	0·00	+ ·011
45	+0·67	− ·033
46	+0·67	− ·019
47	+0·64	− ·010
49	−0·44	+ ·002
50	+0·72	− ·003
51	−0·56	+ ·019
52	+0·71	− ·005
53	−0·58	+ ·017
54	+0·69	+ ·001
55	+0·67	− ·009
56	−1·43	−0·018
56a	+0·72	− ·027
57	−1·38	− ·040
58	−0·98	·000
59	+0·67	+ ·005
60	+0·72	− ·010
61	+0·73	− ·028
62	−0·28	+ ·034
63	+0·72	− ·013
64	+0·72	− ·026
67	−0·88	+ ·005
68	−0·59	+ ·019
69	−1·26	− ·017
70	−0·77	− ·005
71	−0·82	+ ·012
72	−1·58	− ·015
73	−0·32	+ ·009
74	−0·20	+ ·047
75	−1·82	− ·055
76	−0·16	+ ·008
78	−0·57	+ ·007
79	−0·51	− ·007
80	−0·85	+ ·010
81	−0·40	+ ·032
82	−0·60	+ ·004
83	−0·67	+ ·021
84	−0·71	+ ·005
85	−1·08	− ·018
86	−1·55	− ·005
87	−1·37	− ·067
88	+0·72	− ·007
90	+0·68	+ ·001
91	+0·72	− ·021
92	−0·31	+ ·030
93	−0·28	+ ·049
94	−0·39	+ ·013
95	+0·71	+ ·008
96	−0·23	+ ·025
97	+0·70	+ ·055
98	+0·72	− ·028
99	−0·96	+ ·025
100	−0·51	+ ·016
101	+0·67	− ·013
102	−0·38	+ ·039
103	+0·68	− ·013
104	+0·72	− ·032
105	−0·18	+ ·006

Second Series—Gill.

No.	tan ζ cos (p−q).	Res. R
1	+0·54	−0·050
2	+0·71	− ·011
3	+0·65	+ ·002
4	+0·55	+ ·029
6	+0·69	− ·025
7	+0·63	+ ·017
9	−0·94	− ·002
10	−0·85	·000
11	−0·86	− ·019
12	−0·93	+ ·022
14	−0·96	− ·004
15	−0·70	− ·005
16	−0·63	− ·002
17	−0·76	− ·002
19	+0·97	+ ·021
20	+1·04	+ ·019
21	+0·92	+ ·019
23	+0·96	+ ·006
24	+0·88	− ·004
25	+0·98	+ ·006
26	+0·89	+ ·012
27	+1·00	+ ·013
28	−1·29	+ ·001
29	−1·37	− ·025
30	−0·94	− ·013
31	−1·00	+ ·054
32	−0·91	+ ·007
33	−0·82	+ ·014
34	+0·83	− ·006
35	+0·71	− ·015
36	−0·90	− ·004
37	+0·84	− ·038
38	−0·84	+ ·002
39	−0·82	− ·003
40	+1·04	− ·023
41	−0·74	+ ·008
42	+0·98	+ ·010
43	−0·70	− ·004
44	−0·67	− ·012
45	+0·88	+ ·006
46	+0·97	− ·008

First Series—Elkin.

No.	tan ζ cos (p−q).	Res. R
1	+0·01	+0·012
2	−0·42	+ ·018
3	−0·11	− ·022
4	−0·25	− ·013
6	−0·39	+ ·001
7	−0·27	− ·014
8	−0·36	− ·022
9	−0·38	+ ·015
10	−0·26	+ ·011
11	−0·27	− ·028
12	−0·35	+ ·009
13	−0·30	− ·014
14	−0·40	− ·044
15	−0·39	− ·040
16	−0·47	+ ·014
17	−0·50	− ·010
18	−0·30	+ ·010
19	−0·46	+ ·021
22	−0·32	+ ·054
23	−0·48	+ ·039
24	−0·39	+ ·014
25	−0·40	+ ·054
26	−0·14	+ ·020
27	−0·38	+ ·028
28	−0·32	+ ·010
29	−0·35	− ·033
30	−0·32	+ ·006
31	−0·01	− ·023
32	+0·11	− ·013
33	−0·20	− ·018
34	+0·22	− ·011
35	−0·01	− ·032
36	+0·14	− ·001
37	+0·16	− ·020
38	+0·12	− ·027
39	+0·41	− ·007
40	+0·62	+ ·021
41	+0·22	·000
43	+0·71	− ·057
44	+0·38	·000
45	+0·47	− ·032
46	+0·97	+ ·023
47	+0·45	− ·034
48	+1·42	− ·015
49	+0·71	−0·037
50	+1·01	− ·004
51	+1·35	− ·028
52	+1·98	− ·013
53	+2·12	− ·002
54	+0·99	+ ·045
55	+0·89	+ ·018
56	+0·48	+ ·062
57	+0·46	+ ·048
58	+0·28	+ ·038
59	+0·81	+ ·034
60	−0·08	+ ·006
61	+0·71	+ ·016
62	+0·40	+ ·010
63	+0·20	+ ·030
64	+0·75	+ ·036
65	+0·32	+ ·029
66	+0·41	+ ·026
67	−0·33	+ ·013
68	+0·19	+ ·014
69	−0·43	+ ·029
70	+0·27	+ ·001
71	−0·38	− ·013
72	−0·48	+ ·022
73	−0·44	·000
74	−0·04	− ·036
75	−0·39	− ·006
76	−0·50	+ ·029
77	−0·51	+ ·010
78	−0·46	+ ·002
79	−0·51	+ ·004
80	+0·21	− ·056
81	−0·10	− ·017
82	+0·57	− ·002
83	−0·11	− ·023
84	−0·25	− ·029
85	−0·43	− ·004
86	−0·44	− ·004
87	−0·43	− ·007
88	−0·02	− ·015
89	−0·26	− ·032
90	−0·26	+ ·003
91	+0·44	+ ·003
92	−0·14	− ·030

Second Series—Elkin.

No.	tan ζ cos (p−q).	Res. R
1	+1·02	+0·005
2	+0·36	− ·023
3	+0·64	− ·005
4	+1·87	+ ·006
5	+0·93	+ ·010
6	+0·77	− ·016
7	+1·37	+ ·037
8	+1·55	− ·002
9	+1·22	− ·004
10	−0·91	− ·020
11	−1·67	− ·010
12	−0·99	+ ·007
13	−0·90	+ ·019
14	−1·42	− ·022
15	−1·55	− ·032
16	−0·48	+ ·013
17	−0·71	+ ·012
18	−0·90	+ ·012
19	−0·97	+ ·031
20	−0·49	+ ·018
21	−0·58	− ·007
22	−1·62	+ ·004
23	−1·24	− ·028
25	−1·17	+ ·002
26	+1·06	− ·028
27	+1·65	+ ·005
28	+1·43	− ·023
29	+1·62	+ ·023
30	+1·40	− ·020
31	+1·34	− ·007
32	+1·13	+ ·011
33	+1·58	+ ·057
34	−1·14	+ ·086
35	+0·72	− ·021
36	+0·73	− ·012
37	−0·72	+ ·007
38	+0·81	+ ·010
39	−0·76	− ·015
40	−0·70	+ ·027
41	+0·90	− ·029
42	+0·92	+ ·008
43	+0·75	+ ·013
44	−1·08	+ ·020
45	+0·80	− ·058
46	−1·15	+ ·023
47	−0·72	− ·003
48	+0·88	− ·022
49	−1·05	− ·028
50	−1·04	− ·013

Note on Professor Newcomb's Note in the "Monthly Notices" for 1894 November. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

It is evident that Professor Newcomb is either unable or unwilling to seriously discuss the fundamental question which I have raised with respect to the accuracy of our determinations from observation of the variable, t, in terms of which our theoretical results are, or can be made, exact.

And it is useless to attempt to continue a discussion without coming to close quarters on the point at issue.

But it is not desirable that my views should be misrepresented; and it is a misrepresentation of my views for Professor Newcomb to assert that "Mr. Stone maintains that this result" (i.e. the numerical difference obtained by Professor Newcomb) "is due to my failure to apply a certain correction to the numbers of Le Verrier's Tables, which correction is not a function of anything contained in the tables, or of the epoch of any natural event, but of the date when a certain office, three thousand miles away, began to use the tables in computing the solar ephemeris." Such a statement has certainly never been made by me.

The expression for the geocentric longitude of the Sun as a function of 't,' is one thing; the expression for the right ascension of a meridian as a function of 't,' is another thing.

What I have maintained, maintain, and assert that I have proved, is as follows:—That if astronomers use for years, in the determinations of the local sidereal times, a "unit day" which is the $\frac{N}{2\pi}$th part of a mean tropical year, and turn their theoretical expressions into "time" at the rate of 2π to 86,400 mean sidereal seconds; but, for any reasons whatever, at some definite epoch introduce a change and use a "unit day" which is the $\frac{N'}{2\pi}$th part of a mean tropical year: then, simultaneously with the change of units, the mean angular motion, Ω, of the meridians in right ascension must be changed to Ω', so that

$$\Omega : \Omega' = N : N';$$

but in this case we have

$$\Omega - \Omega' = (N - N')\left(1 + \frac{2\pi}{N_0}\right) = N - N' + \frac{2\pi}{N_0}(N - N'),$$

where N_0 will be a definite angle, which, in practice, will not differ much from N or N', but cannot be equal to both N and N'. This result is generally true, and, therefore, true when the N is that of Carlini's, and the N' that of Le Verrier's, Solar Tables.

Now, although Professor Newcomb asserts that the corrections which I introduce are not functions of any natural event, it is a

simple matter of fact that he recognises that changes in Ω and Ω' result from changes in N and N', and he carefully computes the effects of these changes in $\Omega - \Omega'$, and allows for their effects in his work so far as the term $N - N'$ is concerned, but he overlooks and, therefore, neglects the far more important effects which result from the existence of the term

$$\frac{2\pi}{N_0}(N - N').$$

The differences between the numerical results which Professor Newcomb obtains for the local sidereal times at the commencement of each "unit day" and those which I obtain are simply due to the fact that I allow for the effects of the term

$$\frac{2\pi}{N_0}(N - N')$$

and Professor Newcomb neglects them.

If, therefore, Professor Newcomb can prove that no such term as

$$\frac{2\pi}{N_0}(N - N')$$

exists in the difference $\Omega - \Omega'$ under the conditions stated, then his results are right and mine are wrong; but, on the other hand, if the existence of this term is necessary to preserve continuity in our measures of time, then Professor Newcomb's results are wrong and mine are right.

The real question at issue is whether the tabular geocentric places, found as at present, and expressed as a function of t, can be correctly referred to the meridian of an observer without taking account of both the terms

$$N - N' + \frac{2\pi}{N_0}(N - N')$$

in the expression for $\Omega - \Omega'$.

Professor Newcomb apparently considers that it is only necessary, when different fractional parts of a mean tropical year are adopted as the "unit day," to take account of the term $N - N'$; and the result is that Hansen's Lunar Tables, which, when thus compared with observation, gave, comparatively speaking, small residuals from 1750–1863, ceased to represent the observations in 1864, when the data of Carlini's Solar Tables were generally replaced by those of Le Verrier, to such an extent that, although the mean annual residual in 1863 was $-1''{\cdot}54$, there has been no negative mean annual residual since that year, and the residual for 1892 amounted to $+19''{\cdot}69$, and is now over $+20'$. But when allowance is made, as I maintain must be the case to preserve the continuity of our measures of time, for the term

$$\frac{2\pi}{N_0}(N - N')$$

the same tables represent the observations before and after 1864 with equal accuracy.

These are the facts with which observation furnishes us. I leave my readers to draw their own inferences.

See *Monthly Notices* 1894 December.

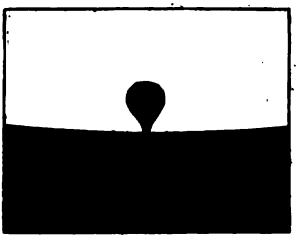
The Transit of Mercury, 1804 *November* 10, *observed in New South Wales.* By H. C. Russell, B.A., F.R.S.

The morning was fine and clear, except a slight haziness. Unfortunately, the Sun was so situated that, viewed from the large equatorial, it was behind the Time-ball Tower. I was therefore obliged to use a very fine 6-inch equatorial by Sir Howard Grubb, which occupies the north dome. This telescope defines admirably, and was for the occasion reduced by a diaphragm to 3 inches. A reflecting prism was used to reduce the light still more, and a power of 120. When the Sun was clear of lower mists, I began to observe the planet carefully. It was remarkably black compared with the Sun-spots, quite round, and fairly well defined. During the whole time I saw no white spot on the planet, or anything to mar its blackness, and there was no surrounding ring or fringe of light. Examined closely, it was seen that at short intervals definition became bad, the apparent vibration producing an ill-defined edge. The rays of the Sun were powerful, and its heating effect no doubt gave rise to currents of unequal temperature, and as these passed before the telescope the planet's limb seemed to be rippling, as if waves were passing over it. As the planet approached the Sun's limb the narrow space between seemed to throw these conditions into prominence, and it became evident, when the planet got within one-third of its diameter (estimated) of the Sun's limb, that the contacts were not to be observed under favourable conditions. A moment of bad definition came on, in which the ripples seemed to form dents in the limbs of planet and Sun from 1′ to 2″ wide, and suddenly a shady ligament joined the limbs of planet and Sun. It was darker near the planet than the Sun's limb, and seemed to be made up of soft shaded lines from limb to limb, making up a band about one-quarter of the planet's diameter wide. This lasted two or perhaps three seconds, and then disappeared. the definition having suddenly improved. The time at which the ligament formed was November 10, $19^h\ 16^m\ 1^s{\cdot}5$. The greater darkness of the ligament near *Mercury* would result from the planet being darker than the sky, and its vibrations would obviously make a darker shading than that caused by the overlapping in vibrations of the darkness outside the Sun's limb. The space between the planet and Sun's limb now became quite clear and free from dark shading, until $19^h\ 16^m\ 18^s{\cdot}5$, when

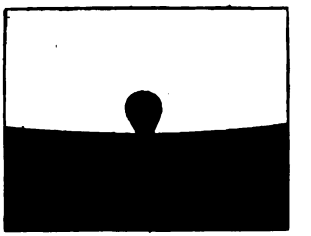
suddenly a wave of bad definition formed the ligament again ; but the limbs were quite evidently not tangential, and did not seem to me to be so until $19^h\ 16^m\ 29^s{\cdot}55$, when I recorded "*Contact of limbs.* Internal contact complete." I then looked carefully to see if the planet's limb could be seen outside the Sun, but I saw no sign of this ; and at external contact the definition was rather better than it had been, and I noted $19^h\ 18^m\ 4^s{\cdot}85$ as the time of last contact.

Mr. G. D. Hirst, who has erected a private observatory about a mile and a half west of Sydney Observatory, has kindly sent me a copy of his observations made with a $3\frac{3}{4}$-inch equatorial of 5 feet focus and good defining power ; aperture reduced to $2\frac{1}{2}$ inches, and magnifying power 100. He says :

"I send herewith two drawings of the black drop seen in the transit of *Mercury* this morning, November 10. These will, I think, be interesting, on account of the black drop phenomena which interfered materially with a satisfactory record of internal



Formation of drop at $7^h\ 16^m\ 22^s{\cdot}9$ S.M.T.



Appearance of drop 6' later.

contact. The drop was totally unlike the phenomenon seen by me at Woodford in 1874 through the finder of the photoheliograph during the transit of *Venus*. That was a fuzzy, ill-defined stalk connecting the limbs of *Venus* and the Sun. This morning *Mercury* appeared to bulge out towards the Sun's limb, and the outline of this drop when formed was perfectly sharp ; and I recorded the time of the formation and apparent contact at $19^h\ 16^m\ 22^s{\cdot}93$ S.M.T. ; and the time of watch was verified immediately afterwards by the transits of *Regulus* and χ *Crucis*. External contact at egress was noted at $19^h\ 18^m\ 2^s$, but this was not very reliable. I used the small aperture for two reasons : first, because I was afraid a larger one would break the coloured glass ; and secondly, I wanted to see if a small aperture had anything to do with the formation of the drop ; and I am now strongly inclined to think it has. Definition was moderately good, at times inferior."

Sydney Observatory :
1894 *November* 11.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1892, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. liv., p. 130, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1892, and Table II. gives the same particulars for the entire year 1892 and for the three preceding years for the sake of comparison. The areas are given in two forms. First, projected areas—that is to say, as seen and measured on the photographs—these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1892 the mean daily area of whole spots, and the mean heliographic latitude of the spotted area, for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results for 1889, 1890, and 1891 being added as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuance of Carrington's series ("Observations of Solar Spots made at Redhill," by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich Civil Time, reckoning from mean midnight.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas.			Corrected for Foreshortening.		
			Umbræ.	Projected Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
512	1892 Jan. 7·64	27	236	1430	2899	195	1224	2997
513	Feb. 3·98	24	397	2436	2954	296	1939	3088
514	Mar. 2·32	27	178	1076	3053	141	843	3143
515	Mar. 29·63	27	167	1071	3275	118	800	3264
516	Apr. 25·89	27	283	1751	3964	206	1361	3931
517	May 23·12	27	260	1786	3213	184	1318	3336
518	June 19·32	28	432	2675	3341	323	2042	3520
519	July 16·52	27	361	2181	3062	260	1640	3049
520	Aug. 12·74	27	207	1390	2790	146	1024	2889
521	Sept. 8·99	28	233	1577	3657	160	1154	2698
522	Oct. 6·27	27	167	1044	3696	121	782	3751
523	Nov. 2·56	27	222	1222	3285	155	924	3152
524	Nov. 29·87	27	177	1140	3273	123	847	3176

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas.			Corrected for Foreshortening.		
		Umbræ.	Projected Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
512	1892 Jan. 7·64	27	636	+21°·99	587	−19°·09	+2°·28	20°·60
513	Feb. 3·98	24	514	17·55	1425	26·86	−15·09	24·39
514	Mar. 2·32	27	401	21·66	442	23·01	−1·79	22·37
515	Mar. 29·63	27	394	13·87	406	19·54	−3·08	16·75
516	Apr. 25·89	27	530	15·00	831	17·01	−4·55	16·23
517	May 23·12	27	657	13·12	661	19·73	−3·35	16·43
518	June 19·32	28	1356	13·73	686	27·89	−0·22	18·49
519	July 16·52	27	1019	12·50	621	20·72	−0·07	15·61
520	Aug. 12·74	27	702	14·97	322	19·55	+4·11	16·41
521	Sept. 8·99	28	632	12·52	522	20·50	−2·40	16·12
522	Oct. 6·27	27	348	13·31	435	22·21	−6·42	18·26
523	Nov. 2·56	27	334	13·25	591	21·20	−8·77	18·33
524	Nov. 29·87	27	361	+14·39	486	−17·29	−3·78	16·05

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
1889	360	5·0	+7°·26	73·0	−11°·90	−10°·68	11°·61
1890	361	53·1	+22·20	46·3	−21·75	+1·73	21·99
1891	363	401	+20·49	169	−19·91	+8·52	20·31
1892	362	607	+15·09	607	−21·69	−3·29	18·39

The principal features of the Sun-spot record for 1892 as brought out by the above tables are:

(1) The continued increase in the mean daily area of umbræ, whole spots, and faculæ. The rate of increase was indeed not so great as in 1891, but the mean values were in each case more than double those for 1891, in the case of the faculæ considerably more than double. (2) The mean daily areas for both whole spots and faculæ already exceeded those in the maximum years of the last solar cycle. (3) And this though the high latitude still occupied by the great majority of the spots would seem to indicate that the maximum had not yet been attained. (4) The predominance of the spots in the northern hemisphere has ceased, the mean daily area of spots being precisely equal for the two hemispheres. (5) Whilst the two hemispheres have shown an equality of spotted area, they have shown a curious difference in its distribution. In the northern hemisphere there has been a marked decline in the mean latitude, and the spots there have almost reached the zone of the period of maximum. In the southern hemisphere, on the contrary, the movement has been actually away from the equator. The rate of increase in the mean daily spotted area has also been very much greater for the southern hemisphere than for the northern. (6) The very remarkable increase in the area of the faculæ. The increase of 1891 over 1890 was at a lower rate for the faculæ than for the spots. This condition has been reversed for 1892, and the mean daily area for faculæ exceeds that of 1882, the maximum year of the last cycle, by considerably more than 1000 millionths.

Royal Observatory, Greenwich:
1895 January 8.

Observations of Occultations of Stars by the Moon, and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1894.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day.	Phenomenon.	Telescope.	Power.	Moon's limb.	Mean Solar Time of Observation. h m s	Observer.
1894 Jan. 12	Disapp. 24 Piscium	E. Equat.	55	Dark	7 1 38·81	C. D.
20	,, *c* Geminorum	,,	200	,,	11 9 38·69	B.
Feb. 13	,, 36 Tauri	Astrographic Equat.	225	,,	12 38 24·34	H. F.
13	,, 36 Tauri	E. Equat.	200	,,	12 38 24·29	W. B.
Mar. 16 (*a*)	,, ω^2 Cancri	,,	55	,,	12 3 1·82	D.
16 (*b*)	,, ω^2 Cancri	Altaz.	100	,,	12 3 0·79	H.
23 (*a*)	Reapp. Piazzi XIII. 317	E. Equat.	100	,,	15 0 55·12	A. C.
25 (*a*)	,, 2 Scorpii	,,	100	,,	15 51 52·21	A. C.
25 (*a*)	,, 3 Scorpii	,,	100	,,	16 19 2·98	A. C.
Apr. 9	Disapp. χ^1 Tauri	Altaz.	100	,,	7 3 46·16	H.
9	,, χ^1 Tauri	E. Equat.	55	,,	7 3 44·99	A. C.
9	,, χ^1 Tauri	Astrographic Equat.	225		7 3 45·99	A. E.
10	,, Piazzi V. 136	E. Equat.	100		10 53 26·15	B.

Day.	Phenomenon.	Telescope.	Power.	Moon's limb.	Mean Solar Time of Observation. h m s	Observer.
1894 Apr. 10	Disapp. Piazzi V. 136	Astrographic Equat.	225	Dark	10 53 26·23	C. D.
11	,, 49 Aurigæ	E. Equat.	100	,,	8 39 39·05	H.
11	,, 49 Aurigæ	Altaz.	100	,,	8 39 39·66	A. C
11	,, 49 Aurigæ	4-inch Detached Tel.	...	,,	8 39 39·44	A. E.
11	,, 49 Aurigæ	Astrographic Equat.	225	,,	8 39 39·44	C. D.
11	,, 49 Aurigæ	Astrographic Finder	...	,,	8 39 39·64	J.
16	Reapp. σ Leonis	Astrographic Equat.	225	Bright	9 29 50·84	A. E.
May 12	Disapp. 37 Leonis	E. Equat.	55	Dark	7 54 7·96	D.
12	,, 37 Leonis	Altaz.	100	,,	7 54 8·43	H. F.
12 (*b*)	,, 37 Leonis	Astrographic Equat.	120	,,	7 54 8·10	C. D.
30	Reapp. ζ^1 Piscium	E. Equat.	55	,,	14 40 10·14	B.
Nov. 15 (*c*)	Disapp. 136 Tauri	,,	55	Bright	7 9 8 82	C. M.
15	,, 136 Tauri	Astrographic Equat.	225	,,	7 9 11·84	C. D.
15	Reapp. 136 Tauri	E. Equat.	55	Dark	7 49 28·27	C. M.
15	,, 136 Tauri	Astrographic Equat.	120	,,	7 49 27·79	C. D.
19	,, 34 Leonis	E. Equat.	200	,,	14 47 2·88	B.

Notes.

(*a*) The time was recorded on the chronograph. (*b*) The disappearance was instantaneous. (*c*) Moon diffused; misty.

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1894 Jan. 17	II.	Ecl. R.	First seen	E. Equat.	55	8 59 0	8 58 52	H. T.
23	I.	Ecl. R.	First seen	Astrographic Equat.	225	11 37 3		H. F.
23	I.		Bisection	,,	,,	11 39 8	11 37 17	,,
23	I.		Full brightness	,,	,,	11 41 47		,,
23	I. (*a*)	Ecl. R.	First seen	E. Equat.	55	11 37 10		O. T.
23	I.		Bisection	,,	,,	11 39 20	11 37 17	,,
23	I.		Full brightness	,,	,,	11 41 5		,,
28	III.	Ecl. R.	First seen	,,	200	6 58 32	7 3 36	A. C.
28	III. (*b*)		Full brightness	,,	,,	7 3 24		,,
28	III.	Ecl. R.	First seen	Astrographic Equat.	225	6 57 43	7 3 36	C. D.
28	III.		Bisection	,,	,,	7 2 50		,,
30	I.	Occ. D.	Bisection	E. Equat.	200	10 1 45	10 4	A. C.
30	I. (*c*)		Last seen	,,	,,	10 4 21		,,
31	I.	Tr. Ing.	First contact	Astrographic Equat.	225	7 14 0		C. D.
31	I.		Bisection	,,	,,	7 16 1	7 15	,,
31	I.		Last contact	,,	,,	7 19 0		,,
Feb. 4	III.	Ecl. D.	Began to fade	E. Equat.	100	9 18 10	9 23 9	H.
4	III. (*d*)		Last seen	,,	,,	9 25 47		,,
18	II. (*e*)	Ecl. D.	Last seen	,,	,,	6 24 35	6 25 19	B.
18	II.	Ecl. R.	First seen	,,	,,	8 41 31	8 41 27	,,
18	III. (*f*)	Occ. D.	First contact	,,	,,	11 46 57	11 54	H.
18	III.		Last seen	,,	,,	11 52 41		,,

Day.	Satellite.	Phenomenon.		Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
						h m s	h m s	
1894 Feb. 24	I. (*g*)	Ecl. R.	First seen	E. Equat.	100	8 18 42	8 18 47	H.
24	I.		Full brightness	,,	,,	8 20 59		,,
Mar. 2	I.	Tr. Ing.	First contact	,,	200	9 26 55		A. C.
2	I.		Bisection	,,	,,	9 28 57	9 27	,,
2	I.		Last contact	,,	,,	9 30 9		,,
3	I.	Occ. D.	Bisection	,,	100	6 46 20	6 47	H.
3	I.		Last seen	,,	,,	6 48 9		,,
4	II. (*h*)	Occ. D.	First contact	,,	,,	8 55 54		,,
4	II.		Bisection	,,	,,	8 58 43	9 3	,,
4	II.		Last seen	,,	,,	9 2 8		,,
10	I. (*i*)	Occ. D.	First contact	Astrographic Equat.	225	8 43 55	8 46	C. D.
11	I.	Sh. Ing.	First contact	,,	,,	7 8 35		,,
11	I.		Bisection	,,	,,	7 9 30	7 8	,,
11	I.		Last contact	,,	,,	7 11 34		,,
11	I.	Tr. Egr.	First contact	E. Equat.	100	8 5 10		H.
11	I.		Bisection	,,	,,	8 7 50	8 9	,,
11	I.		Last contact	,,	,,	8 11 19		,,
11	I. (*j*)	Tr. Egr.	First contact	Astrographic Equat.	225	8 4 21		C. D.
11	I.		Bisection	,,	,,	8 6 15	8 9	,,
11	I.		Last contact	,,	,,	8 9 0		,,
13	II.	Tr. Egr.	First contact	E. Equat.	55	9 16 34	9 20	D.
13	II.		Last contact	,,	,,	9 18 59		,,

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1894 Apr. 10	I. (*k*)	Tr. Ing. First contact	E. Equat.	200	8 23 27	8 25	B.
10	I. (*l*)	Last contact	,,	,,	8 26 0		,,
Sept. 26	I. (*m*)	Occ. R. First seen	,,	100	13 23 36	13 23	H.
26	I.	Last contact	,,	,,	13 27 45		,,
Oct. 27	I.	Tr. Ing. First contact	,,	200	10 15 34	10 20	A. C.
27	I.	Bisection	,,	,,	10 17 31		,,
Nov. 15	II.	Ecl. D. Last seen	,,	55	9 36 39	9 35 21	C. M.
22	II.	Ecl. D. Last seen	,,	200	12 11 4	12 10 34	B.
Dec. 12	I.	Tr. Ing. First contact	28-inch Equat.	370	9 41 49		L.
12	I.	Bisection	,,	,,	9 44 49	9 47	,,
12	I.	Last contact	,,	,,	9 46 46		,,
12	I.	Tr. Ing. First contact	Corbett Equat.	...	9 41 3		C. L.
12	I.	Bisection	,,	...	9 44 46	9 47	,,
12	I.	Last contact	,,	...	9 47 4		,,

Notes.

(*a*) Not good observation. (*b*) Probably early. (*c*) Not a good observation; cloudy.
(*d*) This time may be a few seconds early. The planet was dimmed just at this time, perhaps by passing cloud. The satellite had certainly disappeared 25 seconds later. (*e*) Not a good observation. Sky hazy and J. II. close to limb.
(*f*) Not a good observation. Jupiter very low. (*g*) A good observation. (*h*) Considered a good observation.
(*i*) Cloudy. Doubtful. (*j*) Very windy. (*k*) Very rough. (*l*) Rough.
(*m*) Not a good observation. The time should perhaps be earlier.

: The initials H. T., D., L., H., A. C., B., A. E., H. F., C. M., C. D., W. B., O. T., J., and C. L. are those of Mr. Turner, Mr. Dyson, Mr. Lewis, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Miss Everett, Mr. Furner, Mr. Martin, Mr. Davidson, Mr. Bowyer, Mr. Tuck, Mr. Johns, and Mr. Lacey respectively.

Observations of Encke's Comet made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East, or Sheepshanks, Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to one another, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time.					Observer.	⊕−✱ R.A.	Corr. for Refraction.	Corr. for Parallax.	⊕−✱ N.P.D.	Corr. for Refraction.	Corr. for Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. ✱
1894.	d	h	m	s		m s	s	s	′ ″	″	″		h m s	° ′ ″	
Dec.	27	8	6	12	H.	+0 48·28	−0·02	+0·39	+4 13·4	+0·2	−7·9	6	22 15 5·34	86 20 18·6	*a*
	27	8	11	47	„	+1 33·49	+0·02	+0·39	−2 33·8	−0·2	−7·9	4	22 15 5·79	86 20 16·4	*b*
	30	5	42	52	B.	−1 18·59	+0·01	+0·23	−8 13·2	−0·2	−7·9	3	22 14 23·56	86 42 21·5	*c*
	31	5	54	41	A. C.	+0 48·18	0·00	+0·26	−1 14·4	0·0	−8·0	3	...	...	*d*
1895.															
Jan.	3	5	30	29	B.	+2 18 63	0·00	+0·24	−0 7·5	0·0	−8·2	3	22 13 4·39	87 16 26·3	*e*
	3	5	31	46	„	−0 30·26	0·00	+0·25	+4 47·9	+0 1	−8·2	4	...	...	*f*
	8	5	50	54	A. C.	−0 44 92	0·00	+0·32	+2 7·2	0·0	−8·7	3	22 10 18·08	88 12 15·1	*g*

Notes.

The observations are corrected for refraction and parallax. In computing the latter log Δ has been taken from Dr. Backlund's ephemeris in *Ast. Nach.* 3263, the values used being 9·9315, 9·9238, 9·9208, 9·9110, 9·8905 on December 27, 30, 31, January 3 and 8, respectively. The apparent errors of this ephemeris in R.A. and N.P.D. (tabular−observed) are +0ˢ·78, −17″·5 from star *a*; +0ˢ·28, −13″·6 from star *b*; −0ˢ·84, −11″·1 from star *c*; −1ˢ·13, +10″·6 from star *e*; −2ˢ·10, −2″·4 from star *g*. The observations are also corrected for the error of inclination of the wires, and, where necessary, for the motion of the comet.

December 30.—Sky hazy; clouds passing. Comet bright and distinct, with stellar condensation.

January 3.—The comet was faint, owing to bright moonlight.

The initials H., A. C., B., are those of Mr. Hollis, Mr. Crommelin, and Mr. Bryant, respectively.

Comparison Stars.

	Star's Name.		R.A.		N.P.D.		Authority.
			h m s		° ′ ″		
a	W.B. XXII., 239	1894·0	22 14 14·36	1894·0	86 16 27·6		Albany, Ast. Gesell. Catalogue, Munich, Schjellerup, and Göttingen Catalogues.
b	W.B. XXII., 227		22 13 29·56		86 23 12·9		Albany, Ast. Gesell. Catalogue, Munich and Göttingen Catalogues.
c	B.D. + 2°, 4497		22 15 39·58		86 50 57·2		Albany, Ast. Gesell. Catalogue.
d	B.D. + 2°, 4490		22 13 16·3		86 52·5		Bonn Observations, vol. iii.
e	W.B. XXII., 170	1895·0	22 10 46·27	1895·0	87 16 37·7		Albany, Ast. Gesell. Catalogue and Glasgow Catalogue, 1870.
f	B.D. + 2°, 4491		22 13 34·6		87 12·9		Bonn Observations, vol. iii.
g	B.D. + 1°, 4598		22 11 3·46		88 10 11·7		Munich Catalogue, 1880.

Royal Observatory, Greenwich: 1895 *January* 8.

Observations of Comets Sawerthal, 1888; Davidson, 1889; Wolf, 1891; Holmes, 1892; Rordame-Quénisset, 1893; and Encke, 1894, made at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.*)

The following comet observations were made with the 10-inch Barclay Equatorial, using the ring-micrometer, with power 100.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log $(q \times \Delta)$.	Ref.
				Comet Sawerthal, 1888.									
1888.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
July 3	11 25 22	18 9 57	W.	−0 15·99	−2 48·6	4	1 3 3·58	0·25	9·7295	41 29 56·8	2·6	0·7415	(*a*)
5	11 7 27	17 59 53	F. B.	−3 50·00	−5 34·4	5	1 4 9·22	0·25	9·7276	41 4 25 6	2·7	0·7542	(*b*)
12	11 3 1	18 23 2	R.	+0 15·10	+5 37·5	12	1 7 5·05	0·26	9·7495	39 39 5·6	2·4	0·7169	(*c*)
Aug. 8	12 3 52	21 10 30	W.	−1 2·63	−1 1·6	12	0 59 49·44	0·24	9·7225	35 36 50·6	0·7	0·2077	(*d*)
				Comet Davidson, 1889.									
1889.													
Aug. 6	9 34 48	18 32 11	W.	−3 19·99	−7 24·9	3	14 52 7·59	0·63	9·4767	86 32 5·5	14·0	0·8262	(*e*)
6	9 36 33	18 33 56	W.	+1 11·71	−5 52·9	7	14 52 7·89	0·63	9·4790	86 31 58 3	14·0	0·8264	(*f*)
22	10 26 32	20 27 8	W.	+0 5·08	−0 4·8	12	15 54 1·52	0·48	9·5599	69 7 57·4	7·5	0·7582	(*g*)
Sept. 6	9 48 1	20 47 39	W.	−0 7·81	+1 27·0	9	16 29 31·01	0·36	9·5699	62 33 47·4	4·8	0·7027	(*h*)
				Comet Wolf, 1891.									
1891.													
Sept. 10	15 19 37	2 34 2	R.	+3 4·08	−5 51·6	4	3 53 31·48	0·14	9·1275	67 44 10·6	4·5	0·6473	(*i*)
10	15 35 41	2 50 8	R.	−1 38·00	+1 1·0	3	3 53 33·11	0·11	9·0323	67 44 25·3	4·5	0·6427	(*j*)
11	12 20 9	23 38 1	W.	+0 4·86	+4 54·1	6	3 55 16·44	0·37	9·5500	68 1 40·	5·7	0·7416	(*k*)
Oct. 28	10 40 20	1 3 13	R.	−8 17·88	+0 42·4	3	4 41 33·06	0·37	9·4736	90 32 10·5	8·7	0·8410	(*l*)
Nov. 25	10 18 16	2 31 29	R.	−1 8·93	+6 4·7	8	4 28 14·91	0·21	9·2603	102 2 35·7	8·7	0·8893	(*m*)
25	10 58 0	3 11 20	R.	−0 41·56	−8 24·4	5	4 28 14·20	0·14	9·0893	102 2 55·6	8 8	0·8939	(*n*)
1892.													
Jan. 6	9 25 4	4 31 45	R.	+1 7·93	+4 31·2	8	4 15 15·66	0·02	8·4283	103 39 58·2	6·2	0·9031	(*o*)
6	10 41 9	5 40 1	R.	+2 50·34	−5 9·1	8	4 15 16·02	0·11	9·1329	103 39 38·0	6·2	0 8985	(*p*)

Comet Holmes, 1892.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log $(q \times \Delta)$.	Ref.
1893.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Jan. 20	8 53 26	4 50 12	W.	−0 4·87	+1 56·4	6	1 27 2·17	0·14	9·5313	56 20 54·1	1·6	0·5831	(*g*)

Comet Rordame-Quénisset, 1893.

1893.													
July 10	10 14 19	17 25 29	W.	+3 32·62	−0 26·7	3	8 26 43·38	0·91	9·5814	42 53 4·2	18·0	0·8763	(*r*)
17	10 34 12	18 13 1	W.	−3 8·48	+0 44·0	6	10 55 40·50	0·69	9·6088	57 59 53·6	11·7	0·8335	(*s*)

Comet Encke, 1894.

1895.													
Jan. 8	6 39 28	1 46 40	R.	−3 3·36	−1 24·6	6	22 10 16·97	0·38	9·4712	88 12 44·3	8·8	0·8326	(*t*)

Observers' Remarks.

(*a*) Clouds keep passing. The tail can be traced across the diameter of the ring, but nucleus glimmers out now and then; the end of nebulosity observed. (*b*) Cloudy, but nucleus showed up brightly at times.

(*c*) Very difficult observation; so faint; barely visible at times. The nucleus only seen occasionally.

(*d*) The night exceptionally fine. The comet appeared as the faintest luminous haze; every now and then a coma showed itself as a brightening near the head of the luminosity.

(*e*), (*f*) The nucleus of comet is stellar, but rather dull, of the 9 mag., and surrounded by a coma; strong moonlight prevented a proper estimation of its width; wind gusty and sky hazy. (*g*) Coma encircling a nucleus of 10½ mag.

(*h*) A small, faint patch; stellar nucleus glimpsed at times. Difficult.

(*i*), (*j*) The nucleus, mag. 12, is just within the coma on the following side.

(*k*) Nucleus surrounded by nebulosity. Thin clouds came up. Observations made with great difficulty. (*l*) Nucleus is 12 mag.

(*m*), (*n*) Nucleus 13 mag. Cloudy at times. (*o*), (*p*) Comet exceedingly faint; moonlight.

(*q*) Thin clouds at times. At the commencement of the observations a star of the 11 mag. (the same estimated brightness as the nucleus) preceded so closely that the nucleus appeared to be double. There was no tail, but a fan-shaped coma.

(*r*) Coma is 2′ diameter, and a faint tail seems to proceed north. (On July 16 the comet easily visible to naked eye. Mag. 4.)

(*s*) Cloudy at end. (*t*) Comet faint; moonlight.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F. B., Mr. F. A. Bellamy.

Assumed Places of Comparison Stars.

Ref.	Mean R.A.	Reduction to Apparent R.A.	Mean N.P.D.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	1 3 18·57	+1·00	41 32 34·2	+11·2	Mean of Radcliffe, 1845, 347; Oeltz. Arg. (N.), 1155; Lalande, 2011.
(*b*)	1 7 58·17	+1·05	41 9 48·9	+11·1	Mean of Radcliffe, 1845, 379, and Paris, 1566.
(*c*)	1 6 48·57	+1·38	39 33 17·7	+10·4	Cambridge (Harvard), A. G., 559.
(*d*)	1 0 49·18	+2·89	35 37 46·1	+ 6·2	Mean of Radcliffe, 1845, 329, and Greenwich, 1872, 103, adopting proper motions of +0ˢ·386 in R.A., and +1″·56 in N.P.D.
(*e*)	14 55 26 68	+0·90	86 39 34·1	− 3·7	Albany, A. G., 5111.
(*f*)	14 50 55·31	+0·87	86 37 54·9	− 3·7	Albany, A. G., 5096.
(*g*)	15 53 55·59	+0·85	69 8 13·2	−11·0	Berlin, A. G., Zone 258.
(*h*)	16 29 38·11	+0·71	62 32 34·1	−13·7	Comparisons with W.B. (2) XVI., 985, and W.B. (2) XVI., 998–9.
(*i*)	3 50 25·58	+1·83	67 50 11·6	− 9·4	Radcliffe, 1890, 922.
(*j*)	3 55 9·30	+1·81	67 43 33·6	− 9·3	Radcliffe, 1890, 942.
(*k*)	3 55 9·75	+1·83	67 56 55·1	− 9·4	Comparisons with Radcliffe, 1890, 945.
(*l*)	4 49 48·29	+2·65	90 31 43·0	−14·8	Mean of Paris, 5643, and Göttingen, 1875, 1380–1.
(*m*)	4 29 20·75	+3·09	101 56 43 9	−12·9	Radcliffe, 1890, 1091.
(*n*)	4 28 52·68	+3·08	102 11 32·8	−12·8	Radcliffe, 1890, 1086.
(*o*)	4 14 7·32	+0·41	103 35 24·0	+ 3·0	Radcliffe, 1890, 1028.
(*p*)	4 12 25·27	+0·41	103 44 44·0	+ 3·1	Radcliffe, 1890, 1021.
(*q*)	1 27 7·91	−0·87	56 19 6 0	− 8·3	Radcliffe transit-circle observations, 1894 November 5, December 27.
(*r*)	8 23 10 60	+0·16	42 53 39·1	− 8·2	Paris, 10406.
(*s*)	10 58 48·25	+0·73	57 59 14·7	− 5·1	Leiden, A. G., Zones 170, 284.
(*t*)	22 13 21·08	−0·75	88 14 4·1	+ 4·8	Seeliger's Lamont, 30666.

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distances, Δ, are taken, except in the last case, from the *Astronomische Nachrichten*, as follows:—(*a*), (*b*), (*c*), No. 2838; (*d*), 2846; (*e*), (*f*), 2913 (*g*), (*h*), 2916; (*i*), (*j*), 3045; (*k*), (*l*), 3054; (*m*), (*n*), (*o*), (*p*), 3064; (*q*), 3140; (*r*), (*s*), 3173; (*t*), *Bulletin de l'Académie Impériale des Sciences de St. Pétersbourg*, 1894 Novembre.

Radcliffe Observatory, Oxford: 1895 *January* 10.

Estimations of Magnitude of Nova Aurigæ, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.

Estimations of the magnitude of the *Nova* have been made on the following twenty-three nights :—1893, January 16, 17, 20 ; February 4, 7, 8, 11, 16, 28 ; March 4, 10, 16, 27 ; April 4, 12, 21 ; May 3, 10 ; August 24 ; November 9. 1894, January 12, 23 ; and November 5. No sensible change was detected, the magnitude remaining at 9·7 on the scale published in the *Monthly Notices*, vol. lii. 6, p. 431, where a chart is given of the selected comparison stars.

Ephemerides of the Five Inner Satellites of Saturn, 1895.
By A. Marth.

Greenwich Noon. 1895.		P	L	B	*B*	A−L	Long. of Centr. Mer.	B′
		°	°	°	°	°	°	°
Feb.	25	359·953	215·661	+18·392	+16·808	−5·042	200·66	+20·28
Mar.	2	·940	215·555	18·337	16·865	4·782	105·10	20·22
	7	·922	215·410	18·270	16·921	4·481	9 57	20·14
	12	899	215 226	18·191	16·977	4·141	274·06	20·06
	17	·872	215 005	18·102	17·033	3·765	178·55	19·96
	22	·840	214·751	18 003	17·090	3·356	83 05	19·85
	27	359·805	214·467	+17·896	+17·147	−2·917	347·55	+19·74
Apr.	1	·767	214·157	17·781	17·204	2·451	252·04	19·61
	6	·727	213 824	17 659	17·260	1·963	156·52	19·48
	11	·684	213·474	17·533	17·316	1·458	60·98	19·34
	16	·639	213·111	17·405	17·372	0·940	325·42	19·20
	21	·594	212·740	17·275	17·428	−0·413	229·83	19·06
	26	359·548	212 366	+17·146	+17·484	+0·116	134·21	+18·92
May	1	·503	211·994	17·019	17·539	0·644	38·55	18·78
	6	·458	211·628	16·895	17·594	1·165	302·84	18·65
	11	·415	211·274	16·777	17·650	1 675	207·09	18·52
	16	·374	210·935	16·666	17 705	2·170	111·29	18·40
	21	·335	210·616	16·563	17·760	2·645	15·43	18·29
	26	359·299	210·320	+16·471	+17·814	+3·097	279·52	+18·19
	31	·266	210·051	16·390	17·869	3·521	183·55	18·10
June	5	·237	209·813	16·321	17·924	3 9·5	87·53	18 02
	10	·212	209·607	16·235	17·978	4 277	351·45	17·96
	15	·191	209·436	16·223	18 032	4·604	255·30	17·92
	20	·175	209·301	16·195	18·086	4·895	159·10	17·89
	25	359·163	209·205	+16·182	+18·140	+5·148	62·85	+17·87
	30	·156	209·148	16·184	18 194	5·361	326·54	17·87
July	5	·154	209·130	16·201	18·248	5·535	230·17	17·89
	10	·157	299 152	16·233	18 302	5·669	133·76	17·93
	15	·164	209·214	16·280	18·355	5·764	37 30	17·98
	20	·176	209·315	16·342	18·408	5·820	300·80	18·05
	25	359·193	209·455	+16·417	+18·461	+5·837	204·26	+18·13

P denotes the position-angle of the axis of *Saturn*; L+180° the planetocentric longitude of the Earth referred to the planet's equator; A+180° that of the Sun, or A−L the difference between the two. B and *B* denote the planetocentric latitudes of the Earth and Sun above the planet's equator, the inclination I and node N of which referred to the plane of the Earth's equator are assumed to be for

$$1895{\cdot}0 \quad I = 6°{\cdot}9391 \quad N = 126°{\cdot}0552.$$

The longitudes of *Saturn's* central meridian are a continuation of those given in the ephemerides for 1893 and 1894, the adopted daily rate of rotation being 844°·80. The differences between successive values, for an interval of five days, vary between 4223°·46 and 4224°·50.

The first column in the next table contains *Saturn's* brightness expressed in star-magnitudes according to the formula given by Professor G. Müller in his *Helligkeitsbestimmungen der Planeten*, in vol. viii. p. 366 of the Potsdam publications.

In the uncertainty of the real dimensions of *Saturn's* disc, I have for the present ephemeris adopted 17″·50 and 15″·75 as the values of the diameters at the distance 9·5389 and 40″·20 as that of the ring, though H. Struve's observations of conjunctions of satellites with the ends of the ring give 39″·2 (*v. Monthly Notices*, vol. liv. p. 470) or a value even smaller than Bessel's.

If $e = \sin \epsilon_0$ is the eccentricity of the planet's spheroid, or $\cos \epsilon_0$ the proportion of the polar to the equatorial diameter, the proportion of the apparent semi-axes b and a of the disc as seen from a distant point in planetocentric latitude B will be

$$\cos \epsilon = \cos \epsilon_0 \, . \, \sqrt{1 + \tan^2 \epsilon_0 \sin^2 B},$$

or

$$b = a \cos \epsilon = a \cos \epsilon_0 \, . \, \sec \nu,$$

if

$$\tan \nu = \tan \epsilon_0 \sin B.$$

If y is the distance of a belt from the centre of the disc measured along the polar semi-axis b, the latitude β' of the belt is found by

$$\sin (\beta' - B') = \frac{y}{b}.$$

from which the planetocentric latitude β, if it should be required, may be deduced by

$$\tan \beta = \tan \beta' \, . \, \cos \epsilon_0.$$

The values of B′ found from

$$B' \tan B' = \tan B \sec \epsilon_0$$

are given in the last column of the preceding table.—In the tables for the five satellites, a and b denote the semi-axes of the

apparent orbits, $l-L$ the orbital longitudes reckoned from the points which are in superior conjunction with the planet's centre or in opposition to the Earth in longitude. By adding to $l-L$ the value of L from the preceding table, the longitudes l are found, which are already corrected for the equation of light.

Greenwich Noon.	b's mag.	Semidiameter of Ball. Equat.	Defect.	Polar.	Sem'axis of Ring. Major	Minor.	*Mimas.* a_1	b_1	l_1-L
1895	m	"	"	"	"	"	"	"	°
Feb. 25	0·63	9·01	0·035	8·21	20·71	6·53	27·68	+8·73	151·64
Mar. 2	0·61	9·08	·032	8·27	20·87	6·56	27·89	8·78	261·93
7	0·58	9·15	·028	8·33	21·02	6·59	28·10	8·81	12·25
12	0·55	9·21	·024	8·39	21·16	6·61	28·29	8·83	122·59
17	0·53	9·27	·020	8·44	21·29	6·62	28·46	8·84	232·96
22	0·50	9·32	·016	8·48	21·41	6·62	28·62	8·85	343·35
27	0·47	9·37	·012	8·52	21·52	6·61	28·76	+8·84	93·75
Apr. 1	0·45	9·41	·009	8·56	21·61	6·60	28·88	8·82	204·16
6	0·42	9·44	·006	8·59	21·68	6·58	28·98	8·79	314·58
11	0·40	9·46	·003	8·61	21·74	6·55	29·06	8·75	65·01
16	0·38	9·48	·001	8·62	21·78	6·51	29·11	8·71	175·43
21	0·36	9·49	·000	8·63	21·80	6·47	29·14	8·65	285·84
26	0·35	9·49	...	8·63	21·80	6·43	29·14	+8·59	36·24
May 1	0·37	9·48	·000	8·62	21·79	6·38	29·12	8·52	146·62
6	0·41	9·47	·002	8·60	21·75	6·32	29·07	8·45	256·97
11	0·44	9·44	·004	8·58	21·69	6·26	29·00	8·37	7·30
16	0·47	9·41	·007	8·55	21·62	6·20	28·90	8·29	117·60
21	0·51	9·37	·010	8·52	21·54	6·14	28·79	8·21	227·86
26	0·54	9·33	·014	8·48	21·44	6·08	28·65	+8·12	338·09
31	0·57	9·28	·018	8·43	21·32	6·02	28·50	8·04	88·28
June 5	0·60	9·22	·022	8·38	21·19	5·96	28·33	7·96	198·42
10	0·64	9·16	·026	8·32	21·05	5·90	28·14	7·88	308·52
15	0·67	9·10	·029	8·26	20·90	5·84	27·94	7·81	58·57
20	0·70	9·03	·033	8·20	20·75	5·79	27·74	7·74	168·58
25	0·72	8·96	·036	8·14	20·59	5·74	27·52	+7·67	278·54
30	0·75	8·89	·038	8·08	20·42	5·69	27·30	7·61	28·45
July 5	0·78	8·82	·040	8·01	20·25	5·65	27·07	7·55	138·32
10	0·80	8·74	·042	7·94	20·08	5·61	26·85	7·50	248·15
15	0·82	8·67	·044	7·87	19·91	5·58	26·62	7·46	357·93
20	0·84	8·60	·044	7·81	19·74	5·56	26·39	7·43	107·67
25	0·86	8·52	0·044	7·74	19·58	5·53	26·17	+7·40	217·37

The differences of successive values of l_1-L vary between 1909°·70 and 1910°·43.

	Enceladus.				*Tethys.*			
	a_2	b_2	l_2-L	Diff.	a_3	b_3	l_3-L	Diff.
1895.	"	"	°	°	"	"	°	°
Feb. 25	35·51	+11·20	44·06		43·96	+13·87	278·28	
				1313·87				953·67
Mar. 2	35·78	11·26	277·93		44·30	13·94	151·95	
				·91				·71
7	36·04	11·30	151·84		44·62	13·99	25·66	
				·94				·73
12	36·29	11·33	25·78		44·92	14·02	259·39	
				·96				·77
17	36·51	11·35	259·74		45·20	14·04	133·16	
				1313·99				·80
22	36·72	11·35	133·73		45·45	14·05	6·96	
				1314·01				·82
27	36·90	+11·34	7·74		45·68	+14·04	240·78	
				·03				·84
Apr. 1	37·05	11·32	241·77		45 87	14·01	114·62	
				·04				·85
6	37·18	11·28	115 81		46·03	13·96	348·47	
				·04				·86
11	37·28	11·23	349·85		46 15	13·90	222·33	
				·05				·87
16	37·35	11·17	223·90		46·23	13·83	96·20	
				·04				·87
21	37·38	11·10	97 94		46·27	13·74	330·07	
				·04				·86
26	37·38	+11·02	331·98		46·28	+13 64	203·93	
				·02				953·85
May 1	37·35	10·93	206·00		46·24	13·53	77·78	
				1314·00				·84
6	37·29	10·84	80·00		46·17	13·42	311·62	
				1313·98				·82
11	37·20	10·74	313·98		46 05	13·29	185·44	
				·96				·79
16	37·08	10·63	187·94		45·90	13·16	59·23	
				·92				·77
21	36·93	10·53	61·86		45·72	13·03	293·00	
				·89				·73
26	36·76	+10·42	295·75		45·50	+12·90	166·73	
				·85				·70
31	36·56	10·32	169·60		45·25	12·77	40·43	
				·82				·67
June 5	36·34	10·21	43·42		44·98	12·64	274 10	
				·78				·63
10	36·10	10·11	277·20		44·69	12·52	147·73	
				·73				·59
15	35·85	10·01	150·93		44·38	12·40	21·32	
				·69				·55
20	35·58	9·92	24·62		44·05	12·29	254·87	
				·65				·50
25	35·30	+ 9·84	258·27		43·70	+12·18	128·37	
				·60				·46
30	35·02	9·76	131·87		43·35	12·08	1·83	
				·56				·42
July 5	34·73	9·69	5·43		42·99	12·00	235·25	
				·52				·38
10	34·44	9·63	238·95		42 63	11·92	108·63	
				·47				·33
15	34·15	9·57	112·42		42·27	11·85	341·96	
				·43				·29
20	33·86	9·53	345·85		41·91	11·79	215·25	
				1313·40				953·26
25	33·57	+ 9·49	219·25		41·56	+11·75	88·51	

		Dione.				*Rhea.*			
1895.		a_2	b_2	l_2-L	Diff.	a_2	b_2	l_2-L	Diff.
		″	″	°	°	″	″	°	°
Feb.	25	56·30	+17·76	73·19	657·83	78·63	+24·81	311·17	398·59
Mar.	2	56·73	17·85	11·02	·87	79·23	24·93	349·76	·63
	7	57·14	17·91	308·89	·91	79·80	25·02	28·39	·66
	12	57·53	17·96	246·80	·94	80·34	25·08	67·05	·70
	17	57·89	17·99	184·74	·96	80·84	25·12	105·75	·73
	22	58·21	17·99	122·70	657·99	81·30	25·13	144·48	·75
	27	58·50	+17·98	60·69	658·02	81·70	+25·10	183·23	·78
Apr.	1	58·75	17·94	358·71	·03	82·04	25·05	222·01	·79
	6	58·95	17·88	296·74	·04	82·32	24·97	260·80	·81
	11	59·11	17·81	234·78	·05	82·54	24·87	299·61	·82
	16	59·21	17·71	172·83	·05	82·69	24·74	338·43	·83
	21	59·27	17·60	110·88	·05	82·77	24·58	17·26	·82
	26	59·27	+17·47	48·93	·04	82·77	+24·40	56·08	·82
May	1	59·22	17·33	346·97	·03	82·71	24·21	94·90	·81
	6	59·13	17·18	285·00	658·02	82·57	24·00	133·71	·80
	11	58·98	17·02	223·02	657·99	82·37	23·78	172·51	·77
	16	58·79	16·86	161·01	·96	82·10	23·55	211·28	·75
	21	58·55	16·69	92·97	·94	81·77	23·31	250·03	·73
	26	58·27	+16·52	36·91	·91	81·38	+23·07	288·76	·70
	31	57·96	16·35	334·82	·87	80·94	22·84	327·46	·66
June	5	57·61	16·19	272·69	·83	80·46	22·61	6·12	·63
	10	57·24	16·03	210·52	·80	79·93	22·39	44·75	·59
	15	56·84	15·88	148·32	·76	79·37	22·17	83·34	·56
	20	56·41	15·73	86·08	·72	78·78	21·97	121·90	·51
	25	55·97	+15·60	23·80	·67	78·17	+21·78	160·41	·47
	30	55·52	15·48	321·47	·63	77·54	21·61	198·88	·44
July	5	55·06	15·36	259·10	·60	76·90	21·46	237·32	·39
	10	54·60	15·26	196·70	·55	76·25	21·32	275·71	·35
	15	54·14	15·18	134·25	·51	75·61	21·20	314·06	·31
	20	53·68	15·10	71·76	657·47	74·96	21·09	352·37	398·27
	25	53·22	+15·04	9·23		74·33	+21·01	30·64	

These values are to be interpolated for the times for which the apparent places of the satellites are required, when the position-angles p and distances s, or the rectangular coordinates x and y referred to the axes of the disc of *Saturn*, are found by means of the formulæ

$$s \sin (p-\mathrm{P}) = x = a \sin (l-\mathrm{L})$$
$$s \cos (p-\mathrm{P}) = y = b \cos (l-\mathrm{L}).$$

Approximate Greenwich times of conjunctions of the satellites with the centre of the planet, or of their crossing the direction of the polar axis of the ball; "*n*" satellite north, in superior conjunction, moving from the preceding to the following side; "*s*" satellite south, in inferior conjunction, moving from the following to the preceding side. In the case of Rhea the times of the greatest elongations, "*e*" east, "*w*" west, are also given.

G.M.T. 1895.	h		G.M.T. 1895.	h		G.M.T. 1895.	h	
Feb. 25	10·3	Te. *n*	Mar. 6	0·5	Di. *s*	Mar. 15	14·3	Di. *n*
	12·2	En. *s*		10·1	En. *n*		16·2	Rh. *n*
	13·1	Mi. *n*		11·9	Mi. *s*		22·1	Mi. *s*
	14·7	Rh. *n*		15·4	Rh. *n*	16	0·3	En. *n*
	19·5	Di. *s*		20·8	Te. *n*		7·2	Te. *n*
26	0·4	Mi. *s*		23·2	Mi. *n*		9·4	Mi. *n*
	8·9	Te. *s*	7	9·3	Di. *n*		16·7	En. *s*
	11·7	Mi. *n*		10·5	Mi. *s*		19·3	Rh. *e*
	17·8	Rh. *e*		18·5	Rh. *e*		20·7	Mi. *s*
	21·3	En. *s*		19·0	En. *n*		23·1	Di. *s*
	23·0	Mi. *s*		19·4	Te. *s*	17	5·9	Te. *s*
27	7·6	Te. *n*		21·8	Mi. *n*		8·0	Mi. *n*
	10·3	Mi. *n*	8	11·4	En. *s*		9·2	En. *n*
	13·7	En. *n*		18·1	Te. *n*		19·3	Mi. *s*
	20·9	Rh. *s*		18·1	Di. *s*		22·3	Rh. *s*
	21·6	Mi. *s*		20·5	Mi. *n*	18	8·0	Di. *n*
28	13·2	Di. *s*		21·6	Rh. *s*		17·9	Mi. *s*
	20·2	Mi. *s*	9	16·7	Te. *s*		18·0	En. *n*
	22·6	En. *n*		19·1	Mi. *n*	19	10·5	En. *s*
Mar. 1	15·0	En. *s*		20·3	En. *s*		16·5	Mi. *s*
	18·8	Mi. *s*	10	0·7	Rh. *w*		16·8	Di. *s*
	22·0	Di. *n*		12·8	En. *n*	20	4·5	Rh. *n*
2	17·5	Mi. *s*		15·4	Te. *n*		15·1	Mi. *s*
	23·9	En. *s*		17·7	Mi. *n*		19·3	En. *s*
3	6·2	Rh. *e*	11	11·8	Di. *s*	21	0·5	Te. *s*
	6·8	Di. *s*		14·0	Te. *s*		7·6	Rh. *e*
	16·1	Mi. *s*		16·3	Mi. *n*		11·8	En. *n*
	16·4	En. *n*		21·6	En. *n*		15·7	Mi. *s*
4	0·8	Te. *s*	12	6·9	Rh. *e*		23·1	Te. *n*
	9·3	Rh. *s*		12·6	Te. *n*	22	10·4	Di. *s*
	14·7	Mi. *s*		14·1	En. *s*		10·7	Rh. *s*
	15·7	Di. *n*		14·9	Mi. *n*		12·3	Mi. *s*
	23·5	Te. *n*		20·6	Di. *s*		20·7	En. *n*
5	12·4	Rh. *w*	13	10·0	Rh. *s*		21·8	Te. *s*
	13·3	Mi. *s*		11·3	Te. *s*	23	11·0	Mi. *s*
	17·7	En. *s*	14	9·9	Te. *n*		13·1	En. *s*
	22·1	Te. *s*		13·1	Rh. *w*		13·8	Rh. *w*

1895.	G.M.T. h		
Mar.	23	19·3	Di. ♈
		20·4	Te. ♈
		22·3	Mi. ♈
	24	16·9	Rh. ♈
		19·1	Te. ♉
		20·9	Mi. ♈
		22·0	En. ♉
	25	14·4	En. ♈
		17·7	Te. ♈
		19·5	Mi. ♈
		19·9	Rh. ♐
	26	12·9	Di. ♈
		16·3	Te. ♉
		18·1	Mi. ♈
		23·0	Rh. ♉
		23·3	En. ♈
	27	15·0	Te. ♈
		15·7	En. ♉
		16·7	Mi. ♈
		21·8	Di. ♉
	28	13·6	Te. ♉
		15·3	Mi. ♈
	29	5·2	Rh. ♈
		6·6	Di. ♈
		12·3	Te. ♈
		13·9	Mi. ♈
		17·0	En. ♈
	30	8·3	Rh. ♐
		9·5	En. ♉
		10·9	Te. ♉
		12·6	Mi. ♈
		15·4	Di. ♉
	31	9·6	Te. ♈
		11·2	Mi. ♈
		11·4	Rh. ♉
		18·4	En. ♉
Apr.	1	8·2	Te. ♉
		9·8	Mi. ♈
		10·8	En. ♈
		14·4	Rh. ♍
		21·1	Mi. ♉
	2	6·9	Te. ♈
		8·4	Mi. ♈
		9·1	Di. ♉
		17·5	Rh. ♈
		19·7	En. ♈
		19·7	Mi. ♉
	3	12·1	En. ♉
		17·9	Di. ♈
		18·3	Mi. ♉
		20·6	Rh. ♐
	4	16·9	Mi. ♉
		21·0	En. ♉
		23·7	Rh. ♉
	5	13·4	En. ♈
		15·5	Mi. ♉
	6	11·5	Di. ♈
		14·2	Mi. ♉

1895.	G.M.T. h		
Apr.	6	22·3	En. ♈
	7	0·1	Te. ♉
		12·8	Mi. ♉
		14·7	En. ♉
		20·4	Di. ♉
		22·7	Te. ♈
	8	8·9	Rh. ♐
		11·4	Mi. ♉
		21·4	Te. ♉
	9	12·0	Rh. ♉
		20·0	Te. ♈
	10	14·0	Di. ♉
		15·1	Rh. ♍
		18·7	Te. ♉
	11	17·3	Te. ♈
		17·4	En. ♉
		18·2	Rh. ♈
		18·5	Mi. ♈
		22·8	Di. ♈
	12	9·8	En. ♈
		16·0	Te. ♉
		17·1	Mi. ♈
		21·2	Rh. ♐
	13	7·7	Di. ♉
		14·6	Te. ♈
		15·7	Mi. ♈
		18·7	En. ♈
	14	0·3	Rh. ♉
		11·1	En. ♉
		13·2	Te. ♉
		14·4	Mi. ♈
		16·5	Di. ♈
	15	11·9	Te. ♈
		13·0	Mi. ♈
		20·0	En. ♉
	16	6·5	Rh. ♈
		10·5	Te. ♉
		11·6	Mi. ♈
		12·4	En. ♈
	17	9·2	Te. ♈
		9·6	Rh. ♐
		10·1	Di. ♈
		10·2	Mi. ♈
		21·3	En. ♈
		21·5	Mi. ♉
	18	7·8	Te. ♉
		8·8	Mi. ♈
		12·6	Rh. ♉
		13·7	En. ♉
		19·0	Di. ♉
		20·1	Mi. ♉
	19	15·7	Rh. ♍
		18·7	Mi. ♉
		22·6	En. ♉
	20	15·1	En. ♈
		17·3	Mi. ♉
		18·8	Rh. ♈
	21	12·6	Di. ♉

1895.	G.M.T. h		
Apr.	21	16·0	Mi. ♉
		21·9	Rh. ♐
	22	14·6	Mi. ♉
		16·4	En. ♉
		21·4	Di. ♈
	23	8·8	En. ♈
		13·2	Mi. ♉
	24	6·2	Di. ♉
		11·8	Mi. ♉
		17·7	En. ♈
	25	7·1	Rh. ♈
		10·1	En. ♉
		10·4	Mi. ♉
		15·1	Di. ♈
		21·0	Te. ♉
	26	9·0	Mi. ♉
		10·2	Rh. ♐
		19·0	En. ♉
		19·6	Te. ♈
		20·3	Mi. ♈
	27	11·4	En. ♈
		13·3	Rh. ♉
		18·3	Te. ♉
		18·9	Mi. ♈
	28	8·7	Di. ♈
		16·4	Rh. ♍
		16·9	Te. ♈
		17·6	Mi. ♈
		20·3	En. ♈
	29	12·7	En. ♉
		15·6	Te. ♉
		16·2	Mi. ♈
		17·6	Di. ♉
		19·4	Rh. ♍
	30	14·2	Te. ♈
		14·8	Mi. ♈
		21·6	En. ♉
		22·5	Rh. ♐
May	1	12·9	Te. ♉
		13·4	Mi. ♈
		14·1	En. ♈
	2	11·2	Di. ♉
		11·5	Te. ♈
		12·0	Mi. ♈
	3	10·1	Te. ♉
		10·6	Mi. ♈
		15·4	En. ♉
		20·0	Di. ♈
	4	7·8	Rh. ♈
		7·8	En. ♈
		8·8	Te. ♈
		9·2	Mi. ♈
	5	7·4	Te. ♉
		7·9	Mi. ♈
		10·8	Rh. ♐
		16·7	En. ♈
	6	9·1	En. ♉
		13·7	Di. ♈

G.M.T. 1895.	h		
May	6	13·9	Rh. *s*
	7	17·0	Rh. *w*
	8	10·4	En. *n*
		15·0	Mi. *s*
		20·1	Rh. *n*
	9	7·3	Di. *n*
		13·6	Mi. *s*
		19·3	En. *n*
	10	11·8	En. *s*
		12·3	Mi. *s*
		16·2	Di. *s*
	11	10·8	Mi. *s*
		20·6	En. *s*
		22·0	Te. *n*
	12	9·5	Mi. *s*
		13·1	En. *n*
		20·6	Te. *s*
		20·8	Mi. *n*
	13	8·4	Rh. *n*
		9·8	Di. *s*
		19·3	Te. *n*
		19·4	Mi. *n*
	14	11·5	Rh. *e*
		14·4	En. *s*
		17·9	Te. *s*
		18·0	Mi. *n*
		18·6	Di. *n*
	15	14·6	Rh. *s*
		16·5	Te. *n*
		16·6	Mi. *n*
	16	15·2	Te. *s*
		15·2	Mi. *n*
		15·7	En. *n*
		17·7	Rh. *w*
	17	8·1	En. *s*
		12·3	Di. *n*
		13·8	Te. *n*
		13·8	Mi. *n*
		20·7	Rh. *n*
	18	12·5	Mi. *n*
		12·5	Te. *s*
		17·0	En. *s*
		21·1	Di. *s*
	19	9·5	En. *n*
		11·1	Mi. *n*
		11·1	Te. *n*
	20	9·7	Mi. *n*
		9·8	Te. *s*
		18·3	En. *n*
	21	8·4	Te. *n*
		10·8	En. *s*
		14·8	Di. *s*
		19·6	Mi. *s*
	22	7·1	Te. *s*
		9·1	Rh. *n*
		18·2	Mi. *s*
		19·7	En. *s*

G.M.T. 1895.	h		
May	23	12·1	En. *n*
		12·2	Rh. *e*
		16·8	Mi. *s*
	24	8·4	Di. *s*
		15·3	Rh. *e*
		15·4	Mi. *s*
	25	13·4	En. *s*
		14·1	Mi. *s*
		17·3	Di. *n*
		18·4	Rh. *w*
	26	12·7	Mi. *s*
		21·4	Rh. *n*
	27	11·3	Mi. *s*
		14·7	En. *n*
	28	9·9	Mi. *s*
		10·9	Di. *n*
	29	16·1	En. *s*
		19·8	Di. *s*
		19·8	Mi. *n*
		20·3	Te. *s*
	30	8·5	En. *n*
		18·4	Mi. *n*
		18·9	Te. *n*
	31	9·8	Rh. *n*
		17·1	Mi. *n*
		17·4	En. *n*
		17·6	Te. *s*
June	1	9·8	En. *s*
		12·9	Rh. *e*
		13·4	Di. *s*
		15·7	Mi. *n*
		16·2	Te. *n*
	2	14·3	Mi. *n*
		14·9	Te. *s*
		16·0	Rh. *s*
	3	13·5	Te. *n*
		19·1	Rh. *w*
	4	12·2	Te. *s*
	5	10·1	Mi. *n*
		10·8	Te. *n*
		12·5	En. *s*
		15·9	Di. *n*
	6	9·5	Te. *s*
	7	8·1	Te. *n*
		13·8	En. *n*
		18·7	Mi. *s*
	8	7·4	Rh. *w*
		9·6	Di. *n*
		17·3	Mi. *s*
	9	10·5	Rh. *n*
		15·1	En. *s*
		15·9	Mi. *s*
		18·4	Di. *s*
	10	13·6	Rh. *e*
		14·5	Mi. *s*
	11	13·2	Mi. *s*
		16·4	En. *n*

G.M.T. 1895.	h		
June	11	16·7	Rh. *s*
	12	8·9	En. *s*
		11·8	Mi. *s*
		12·1	Di. *s*
		19·8	Rh. *w*
	13	10·4	Mi. *s*
		17·7	En. *s*
		20·9	Di. *n*
	14	9·0	Mi. *s*
		10·2	En. *n*
		20·3	Mi. *n*
		21·3	Te. *n*
	15	18·9	Mi. *n*
		19·1	En. *n*
		20·0	Te. *s*
	16	11·5	En. *s*
		14·6	Di. *n*
		17·6	Mi. *n*
		18·6	Te. *n*
	17	8·2	Rh. *w*
		16·2	Mi. *n*
		17·3	Te. *s*
	18	11·3	Rh. *n*
		12·9	En. *n*
		14·8	Mi. *n*
		15·9	Te. *n*
	19	8·3	Di. *n*
		13·4	Mi. *n*
		14·4	Rh. *e*
		14·6	Te. *s*
	20	12·0	Mi. *n*
		13·2	Te. *n*
		14·2	En. *s*
		17·1	Di. *s*
		17·5	Rh. *s*
	21	10·6	Mi. *n*
		11·9	Te. *s*
		20·6	Rh. *w*
	22	Transit of Venus across Sun's disc (*v. M.N.* vol. liv. p. 173)	
		9·3	Mi. *n*
		10·5	Te. *n*
		15·5	En. *n*
	23	9·2	Te. *s*
		10·8	Di. *s*
	24	16·8	En. *s*
		17·8	Mi. *s*
	25	9·3	En. *n*
		16·2	Mi. *s*
	26	9·0	Rh. *w*
		15·0	Mi. *s*
		18·2	En. *n*
	27	10·6	En. *s*
		12·1	Rh. *n*
		13·3	Di. *n*

G.M.T. 1895.	h		G.M.T. 1895.	h		G.M.T. 1895.	h	
June 27	13·7	Mi. *s*	July 4	9·6	Di. *s*	July 7	13·0	Te. *n*
28	12·3	Mi. *s*		17·0	Te. *s*		16·1	Rh. *s*
	15·2	Rh. *s*	5	9·8	Rh. *w*	8	11·7	Te. *s*
29	10·9	Mi. *s*		15·7	Te. *n*		12·1	Di. *n*
	11·9	En. *n*		18·4	Di. *n*	9	10·3	Te. *n*
	18·3	Rh. *s*	6	13·0	Rh. *n*	10	9·0	Te. *s*
July 1	15·9	Di. *s*		14·4	Te. *s*			

Col. Cooper's Observatory,
Markree, Colloonsy, Ireland.

Erratum in *Monthly Notices*, vol. liv., No. 9, p. 262, of List of Presents, last paragraph but one from bottom, *for* J. M. Schaeberle *read* Lick Observatory.

Erratum in *Monthly Notices*, vol. liv., No. 9, p. 581: Comparison of Gale's Comet with stars *f* and *g* on 1894 June 28. In column of Greenwich Mean Solar Time *for* $28^d\ 11^h\ 19^m\ 3^s$ *read* $28^d\ 11^h\ 4^m\ 3^s$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. FEBRUARY 8, 1895. No. 4

CAPTAIN W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

Edwin Bare, Ruthven Villa, Hainault Road, Leytonstone ;
Vincent Joseph Bouton, B.Sc., 9 Lansdowne Terrace, Hampton Wick ;
Comte A. de la Baume Pluvinel, 7 rue de la Baume, Paris ;
Henri Deslandres, D. ès Sc., Astronome-Adjoint à l'Observatoire de Paris ;
George Darley Lardner, 6 Princes Road, South Wimbledon ;
Charles William Dyson Perrins, Davenham Bank, Malvern ;
Charles A. Post, 21 Washington Square, N., New York City, U.S.A. ;
Charles Roberts, Westerham Woods, Mumhurst Road, Bournemouth ;

were balloted for and duly elected Fellows of the Society.

Report of the Council to the Seventy-fifth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1893	249	386	1	636	46	1	683
Since elected	+5	+30	...	...	+2	...	...
Deceased	−9	− 8	...	...	...	...	...
Resigned	...	− 8	...	...	...	...	...
Removals	+2	− 2	...	...	...	...	...
Expelled	...	− 6	...	...	...	...	...
December 31, 1894	247	392	1	640	48	1	689

Dr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, 1894 January 1:—						
At Bankers', as per Pass Book	365	15	11			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	11	2	3			
In hand of Assistant Secretary on Petty Cash Account	0	1	4			
				376	19	6
Dividends on £13,200 Consols, 2¾ per cent. ...	351	13	6			
„ on £900 New 2½-per-cent. Stock ...	20	5	8			
„ on £1,250 Metropolitan 3-per-cent. Stock	36	5	10			
				408	5	0
Received on account of Subscriptions:—						
Arrears	155	8	0			
Annual Contributions for 1894	571	4	0			
„ „ 1895	4	4	0			
Admission Fees	67	4	0			
First Contributions	46	4	0			
				844	4	0
Composition Fees				147	0	0
Sales of Publications:—						
At Williams & Norgate's, 1893	14	19	3			
At Society's Rooms, 1894	41	8	6			
				56	7	9
Income Tax refunded by Commissioners of Inland Revenue				11	14	7

Audited and found correct, 1895 January 7.

W. B. Gibbs,
H. P. Hollis,
J. E. Drower.

£1,844 10 10

Astronomical Society, from 1894 *January* 1 *to December* 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
„ „ for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
House Duty	2	12	6			
Fire Insurance	7	16	6			
				10	9	0
Printing	393	2	0			
Plates (Woodbury type)	15	17	6			
				408	19	6
Turnor and Horrox Fund: Purchases for Library	17	13	8			
Binding Books in Library	28	3	0			
Copying Photographs	5	18	0			
				51	14	8
Eclipse Expedition: Balance of Expenses... ...				12	12	4
Clerk's Wages	40	17	6			
Postage and Telegrams	67	18	3			
Carriage of Parcels	4	3	5			
Stationery and Office Expenses	11	5	8			
				124	4	10
Expenses of Meetings	20	0	0			
Lantern Expenses	22	5	3			
				42	5	3
House Expenses	61	7	4			
Coals and Gas	52	18	6			
Electric Light Expenses	13	6	2			
Rental of Wire for Time Signal	5	0	0			
Furniture, Fittings and Repairs	40	10	1			
Sundries	7	7	3			
				180	9	4
Lee and Janson Fund Grants	24	0	0			
Balance of Mrs. Jackson Gwilt's Annuity	1	7	0			
				25	7	0
Purchase of £250 New 2½-per-cent. Stock, at 97⅞, including Commission				245	1	3
Bankers' deductions on cheques				0	1	10
Balances, 1894 December 31:—						
At Bankers', as per Pass Book	391	15	1			
Country Cheque not credited till 1895 ...	23	2	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	13	8	7			
In hand of Assistant Secretary on Petty Cash Account	15	0	2			
				443	5	10
				£1,844	10	10

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1894, and have found and certified the same to be correct. The cash in hand on 1894 December 31, including the balance at the bankers', &c., amounted to £443 5*s.* 10*d.*

The funded property of the Society has been increased during the last year by the purchase of £250 new 2½ per cent. stock.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrears for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

(Signed) W. B. Gibbs,
J. E. Drower,
H. P. Hollis.

January 7, 1895.

Trust Funds.

The Turnor Fund: A sum of £450 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £100 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £323 16*s.* 6*d.* 2¾-per-cent. Consols, the interest to be given by the Council to the widow or orphan of any deceased Fellow or Associate of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £300 2¾-per-cent. Consols, the interest to be given in medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1895 January 1.

	£	s.	d.	£	s.	d.
Balances, 1894 December 31:—						
At Bankers', as per Pass Book	391	15	1			
Outstanding cheque	23	2	0			
In hand of Assistant Secretary on account of Turnor and Horrox Funds	13	8	7			
In hand of Assistant Secretary on Petty Cash Account	15	0	2			
				443	5	10
Due on account of Subscriptions:—						
11 Contributions of 4 years' standing	92	8	0			
9 „ 3 „	56	14	0			
28 „ 2 „	117	12	0			
63 „ 1 „	132	6	0			
2 Admission Fees, &c....	6	6	0			
	405	6	0			
Less 2 Contributions paid in advance ...	4	4	0			
				401	2	0
Due from Messrs. Williams & Norgate for sales of Publications during 1894				7	3	7

£13,200 2¾-per-cent. Consols, including the Turnor and Horrox Memorial Fund, the Lee and Janson Fund, and the Jackson Gwilt Fund.

£900 New 2½-per-cent. Consols.

£1,250 Metropolitan 3-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments; Furniture, &c.

Unsold Publications of the Society.

2 Gold Medals.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXX.	155	...
I. Part 2	42	...	XXXI.	138	...
II. Part 1	51	3	XXXII.	150	...
II. Part 2	17	3	XXXIII.	158	1
III. Part 1	65	1	XXXIV.	161	3
III. Part 2	83	1	XXXV.	106	4
IV. Part 1	78	3	XXXVI.	189	8
IV. Part 2	90	3	XXXVII. Part 1	335	8
V.	102	3	XXXVII. Part 2	280	8
VI.	120	6	XXXVIII.	265	1
VII.	142	3	XXXIX. Part 1	233	3
VIII.	126	3	XXXIX. Part 2	238	3
IX.	133	3	XL.	256	1
X.	145	...	XLI.	404	1
XI.	152	...	XLII.	229	3
XII.	159	...	XLIII.	231	1
XIII.	158	...	XLIV.	210	1
XIV.	365	...	XLV.	244	...
XV.	137	...	XLVI.	224	3
XVI.	163	1	XLVII. Part 1	3	...
XVII.	146	1	XLVII. Part 2	18	...
XVIII.	138	1	XLVII. Part 3	2	...
XIX.	148	...	XLVII. Part 4	10	...
XX.	137	1	XLVII. Part 5	8	...
XXI. Part 1	310	...	XLVII. Part 6	9	...
XXI. Part 2	98	...	XLVII.	199	2
XXI. 1 & 2 (together)	59	...	XLVIII. Part 1	240	1
XXII.	161	1	XLVIII. Part 2	245	1
XXIII.	145	1	XLIX. Part 1	407	1
XXIV.	152	1	XLIX. Part 2	277	2
XXV.	162	...	L.	289	1
XXVI.	168	1	Index to *Memoirs*	630	3
XXVII.	420	1			
XXVIII.	379	...			
XXIX.	401	...			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	57	...	XXIX.	51	...
II.	59	...	XXX.	64	2
III.	...	...	XXXI.	93	...
IV.	...	...	XXXII.	112	5
V.	...	...	XXXIII.	94	...
VI.	45	...	XXXIV.	66	1
VII.	2	...	XXXV.	55	...
VIII.	153	2	XXXVI.	28	1
IX.	24	3	XXXVII.	35	3
X.	172	1	XXXVIII.	98	2
XI.	184	...	XXXIX.	95	...
XII.	106	2	XL.	108	3
XIII.	177	2	XLI.	108	5
XIV.	176	3	XLII.	117	1
XV.	168	2	XLIII.	114	2
XVI.	154	2	XLIV.	117	2
XVII.	167	1	XLV.	119	1
XVIII.	244	...	XLVI.	114	...
XIX.	52	...	XLVII.	132	2
XX.	32	...	XLVIII.	124	1
XXI.	16	...	XLIX.	118	9
XXII.	31	...	L.	120	11
XXIII.	18	...	LI.	121	9
XXIV.	23	...	LII.	119	12
XXV.	14	...	LIII.	121	17
XXVI.	10	1	LIV.	123	25
XXVII.	3	...	Index ...	559	5
XXVIII.	70	...			
Library Catalogue				566	2

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LIV., no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatorial.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatorial.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatorial, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.
„ 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.

No. 30. (4) 3¼-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

„ 31. (5) 2¾-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, 2¾-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, 2⅛-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass 1⅝-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass 1⅞-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

No. 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.
„ 47. (21) Box sextant; reflecting plane and level.
„ 48. (22) Prismatic compass, by Troughton and Simms.
„ 49. (23) Mountain barometer.
„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.
„ 51. (25) Ordinary 4½-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9½-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.

No. 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. 3½-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.
„ 91. Astronomical time watch case, by Professor Chevalier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 117. } Two old sun-dials.
„ 118. }
„ 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.

No. 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eye-pieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-inch portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere, presented by Prof. Slater.
„ 130. 10-inch brass pillar sextant, by Troughton, presented by Dr. Nevins, as executor of the late Mr. A. E. Nevins.
„ 131. Double box sextant, by Cary, presented by Dr. Nevins, as executor of the late Mr. A. E. Nevins.

Besides the above, there is the following apparatus available for eclipse work :—

4 Slits for spectroscope.
2 Abney lenses used in photographing the corona.
2 Dallmeyer negative enlarging lenses.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 10. Variation transit, to Mr. Maxwell Hall.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 22. The *Matthew* equatorial, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. (1) 30-inch transit and stand, to Mr. B. T. Moore.
„ 29. (3) Wire micrometer (No. 1), to Mr. C. Thwaites.
„ „ „ Wire micrometer (No. 2), to Mr. Maxwell Hall.
„ 30. (4) 3¼-inch equatorial and stand, to Mr. E. B. Powell.
„ „ „ Double-image micrometer, to Mr. Maxwell Hall.
„ 31. (5) 2¾-inch telescope and stand, to Mr. F. J. Wardale.
„ 38. (12) 18-inch *Borda* repeating circle, to Mr. Maxwell Hall
„ 42. (16) Artificial horizon, roof, and mercury bottle, to Mr. C. Thwaites.
„ 43. (17) Hassler's reflecting circle, to Mr. B. T. Moore.
„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.
„ 52. (26) Dipping needle, to Mr. Maxwell Hall.
„ 54. (28) Magnetic intensity needle, to Mr. Maxwell Hall.

No. 57. (31) Box sextant and artificial horizon, to Mr. R. J. Lecky.
„ 69. (43) Telescope with rock-crystal object-glass, to Dr. W. Huggins.
„ 76. 5-prism direct vision hand spectroscope, to Mr. E. B. Knobel.
„ 78. 9¼-inch reflector and stand, to Mr. Maxwell Hall.
„ 79. Spectroscope to Mr. Maxwell Hall.
„ 85. Double-image micrometer, to Mr. B. T. Moore.
„ 99. 12-inch portable transit instrument, to Mr. H. T. Vivian.
„ 119. Specimens of diffraction gratings, to Mr. B. T. Moore.
„ 120. 6-prism spectroscope, by Browning, to Mr. C. Thwaites.
„ 123. 6-inch refractor, by Grubb (object-glass only) to Mr. W. E. Wilson.
„ 125. 6-inch refractor by Simms, to Dr. A. A. Common.
„ 126. 3½-inch portable refractor, by Tulley, to Mr. H. Sadler.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Dr. Isaac Roberts, for his photographs of Star Clusters and Nebulæ.

Publications of the Society.

Volume LI., Part III. of the *Memoirs* has been published during the past year, containing the following paper:—

"Comparison of the Greenwich Ten-Year Catalogue (1880) with the Cape Catalogue (1880)." By H. H. Turner and H. P. Hollis.

The attention of foreign and American astronomers is requested to the following paragraph in the Report of the Council for 1879. It is against the rules of the Society to print any paper previously published: "The Council hope that the communication between English and foreign astronomers will continue to increase, but they take this opportunity of mentioning that some of the papers which have been received by the Society have not been printed, on account of their having been previously published abroad."

Obituary.

The Council regret that they have to record the loss by death of the following Fellows during the past year :—

John Whitehouse Frederick Allnutt.
Charles Carpmael.
Arthur Cayley.
Samuel Palmer Chapman.
Edwin Clark.
Sir James Cockle.
P. Edward Dove.
Augustus S. Harrison.
Benjamin John Hopkins.
Richard Johnson.
George Knott.
James Leigh.
John Morgan.
William Peters.
Arthur Cowper Ranyard.
Rev. Henry Roe.
John Spencer.
William Tomlinson.
George Wall.

The Obituary Notice of Professor Cayley is unavoidably deferred. It is hoped that it may be printed in the next number of the *Monthly Notices*.

John Whitehouse Frederick Allnutt was born 1858 May 31. He showed ability very early, and could read fluently at four years old. He was educated at Mr. Thomas Smith's school, Southsea (1871–75); King's College, London (1875–79); University College, London (1881-82); and at the University of Cambridge as a non-collegiate student (1882–85). In 1883 he was awarded the Clothworkers' Exhibition as the most promising non-collegiate student of his year. He overtaxed his strength in reading for his degree, and in the Mathematical Tripos, 1885, his name appeared among the Senior Optimes. In 1883 he worked at practical astronomy under Mr. Turner, who was then demonstrator to the Plumian Professor of Astronomy at Cambridge, and he afterwards succeeded Mr. Turner in this capacity. He entered into the research work of the Plumian Professor with

the greatest devotion and zeal, carrying out long and laborious computations under his direction. Professor Darwin has more than once testified to the great accuracy of his work, which, although to a large extent numerical, was far from being such as could have been undertaken by a mere computer. It is doubtless due to the absorbing nature of this work that Mr. Allnutt communicated no papers of his own to the Society; he took, however, a considerable interest in our proceedings, and attended our meetings with a regularity which is the more noteworthy when it is remembered that this attendance involved a long railway journey, and that his income was not a large one. His somewhat sudden death on 1894 January 27 was due to the after-effects of influenza. He had never been very strong, and for some few years his health had been far from good. A few days before his death, however, he had appeared to recover his strength, and was preparing for work again.

He was elected a Fellow on 1887 December 9.

CHARLES CARPMAEL was born at Streatham Hill, Surrey, on 1846 September 19. He was educated at the Clapham Grammar School, under the Rev. Charles Pritchard, and gained a Minor Scholarship at St. John's College, Cambridge, in 1865. He was elected a Foundation Scholar in 1868, and graduated as Sixth Wrangler in 1869. He was elected a fellow of St. John's College in 1870; in that year he was a member of the British Eclipse Expedition, observing the eclipse with the spectroscope at Estepona, near Gibraltar; in 1871 he visited the United States and Canada, and settled at Toronto in 1872. In 1876 he was made Director of the Magnetic and Meteorological Observatory in Toronto, and in 1880 Director of the Meteorological Service of Canada. He was specially interested in magnetic observations, and devised an ingenious automatic temperature correction for the bifilar suspension of a magnet. He developed the Canadian Weather Bureau, and made many attempts to establish tide-gauges at various points on the coast, though the instruments were several times swept away by severe storms. On the formation of the Royal Society of Canada in 1882 he was appointed Vice-President of the Mathematical, Chemical, and Physical Section, and in 1885 was elected President. He served on three committees of the British Association.

He married in 1876 a daughter of the late Walter Mackenzie, Chief Clerk of the County Court, Toronto. For some time past he had been staying in the south of England for his health, and he died at Hastings on 1894 October 20. He was elected a Fellow in 1873; his papers contributed to this Society, to the Royal Society of Canada, and to the British Association, were chiefly mathematical, two of them dealing with the theory of errors. He drew up the report on the observations made in Canada of the Transit of *Venus* in 1882, and in conjunction with Professor McLeod determined the longitude of Toronto.

EDWIN CLARK was born at Marlow on 1814 January 7. His father was a small tradesman, and manufacturer of the pillow-lace for which the neighbourhood was renowned—an industry which came to an end on the introduction of machinery. Edwin was the eldest of three boys. (His brother, Latimer Clark, F.R.S., is well known in the scientific world, and is also a Fellow of this Society.) After boarding at an old school in the town he was at the age of eleven sent to a French school in Normandy, where in three years he acquired such a thorough knowledge of French that his translation of the *Chronicles of the Canongate* into French was published in France. He returned home in 1828, and was placed in a solicitor's office; but scientific tastes seriously interfered with his application to this work. Such tastes were but little understood at the time, and the boy was regarded by all his friends as a ne'er-do-well. But his diligence and attention to science, especially in its practical aspects, ultimately bore fruit. He obtained a position as teacher in his old school, and one of his colleagues, who was reading for the University, strongly urged the advantage he would derive could he go up for honours at Cambridge. A small legacy of 130*l.* which his mother received at this time was devoted to this purpose. But at the end of two and a half years the legacy and the trade of lace-making had both come to an end, and his impoverished parents found it impossible to continue his maintenance at the University. After some engagements as schoolmaster, Mr. Clark resolved on an apparently reckless project. He had long wished to see something of the world, and with ten pounds in his pocket and a knapsack on his back he started on a wild and indefinite tour on the Continent. He visited the Rhine, Switzerland, and crossed the Alps into Italy, making observations on glaciers and meteorology, and various scientific collections. He became an artist, and continued his tour through Rome to Naples, Pompeii, Salerno Pæstum, and at length returned to his home at Marlow in 1839, to the great delight of his father and mother. He at once accepted a mathematical mastership at Coombe Wood, and then at Brook Green, Hammersmith, and collected a small library and a stock of scientific apparatus.

But this profession did not hold him long. In 1845 the railway mania had resulted in the great financial crisis which threw so many surveyors and engineers out of employment; and at this inopportune juncture he suddenly abandoned the school to assist in the survey of the proposed line between Brighton and Oxford. This project speedily collapsed, but Clark's determination to be an engineer was taken. With an introduction of the most slender character, he repaired to Mr. R. Stephenson's chambers in Great George Street, an office that was destined afterwards to become his own for so many years. Mr. Stephenson was at that time overwhelmed with work, especially in the great contest between the broad and narrow gauge, and Mr. Clark was at once informed of the hopeless improbability of a personal inter-

view. But, nothing daunted, he waited patiently for hours every day in the ante-room during a period of three weeks, and at last was rewarded by a chance interview. He was fortunate enough to be able to prove his abilities almost immediately, and the foundation of his career as an engineer was laid.

The problem on which he won his spurs was that of the Britannia and Conway Tubular Bridges, for the construction of which he was ultimately placed in absolute control as resident engineer. He was for many years chief engineer to the Electric Telegraph Company, and invented and patented the hydraulic graving dock and canal lift. He constructed the great dock at Bombay, and others at Malta and London. He was the designer of a host of bridges, including the great swing bridges at Arnheim, Lyons, and Rochester, the Aire Tubular Bridge, and the Scarborough Viaduct. He was the original inventor of the block system of signalling. Mr. Clark also laid the cable from Dungeness to Holland, and negotiated the agreements and erected the telegraph for the chief English railways. He was engineer to the Crystal Palace Company, and completed the building of the Palace after the fire.

Mr. Clark was singularly careless about money; in early life he had known poverty, and in 1873 his contracts amounted in the aggregate to five millions and a half. The change of fortune affected him but little. He retired entirely from all business in 1876, travelled for two years in South America, and finally settled down in Cromwell House in his native town. His habits were of the most simple description, but he always enjoined the maxim "that a day had been entirely lost if at its close the practical power had not been acquired of doing something that could not be done before," and his genial, happy disposition was fitly represented by his favourite motto, engraven on his sun-dial, *Horas non numero nisi serenas.*

Mr. Clark was elected a Fellow on 1858 July 9, but contributed no papers to the Society. He had, however, a keen interest in astronomy, as in all other branches of science. He was the owner of a fine 8-inch refractor by Ross, and continually used it until within a year or two of his death. He had a good astronomical library, and kept a very careful meteorological record at Marlow.

In a public lecture at Great Marlow, such as he delighted to give, he has described his early astronomical education, which began with naked-eye observations of the Moon and stars as they appeared and disappeared among the tall chimneys from a window in the East End of London. These chimneys were his transit-wires. An old German in the neighbourhood lent a copy of "Ferguson's Astronomy," and "I soon calculated eclipses, and mounted a cardboard transit instrument and equatorial on a water-butt at the back of the house."

Mr. Clark died from internal cancer on 1894 October 22. He

had suffered for some three years, and bore his long and painful illness with exemplary fortitude and patience until the last.

JAMES COCKLE was born on 1819 January 14, being the second son of the late James Cockle, formerly of Great Oakley, Essex. He was educated at Charterhouse (1829–31), and afterwards by private tuition. He left England in 1835 November, for a year's sojourn in the West Indies and the United States. On 1837 October 18, he entered Trinity College, Cambridge, graduating in 1841 (Stokes' year) as 33rd Wrangler. His subsequent eminence as a mathematician is thus a considerable encouragement to those whose position in the Tripos falls short of their expectations. Mr. Cockle was entered as a student at the Middle Temple in 1838, and practised as a special pleader, 1845–49; he was called to the bar at the Middle Temple on 1846 November 6, and joined the Midland Circuit at the Nottingham Spring Assizes in 1848. In 1862 April he draughted the "Jurisdiction in Homicides Act" (Imperial). From 1863 to 1879 he was Chief Justice of Queensland, and was knighted in 1869. He was Senior Commissioner for the consolidation of the Statute law of Queensland. He returned to England in 1879, and from that time till his death his leisure was devoted to the writing of mathematical papers and the affairs of several learned societies. He was elected a Fellow of this Society on 1854 March 10, and served on the Council from 1888 to 1892. He was elected a Fellow of the Royal Society on 1865 June 1, and of the London Mathematical Society on 1870 June 9, filling the Presidential Chair from 1886–88. He was President of the Queensland Philosophical Society 1863–79, and was an honorary member of the Royal Society of New South Wales.

His mathematical papers number more than eighty, and, with the exception of four on the motion of fluids, deal entirely with pure mathematics.

In the Savage Club (London), of which he was treasurer 1884–89, it was a familiar sight to see him quietly working at some algebraical research on the back of an envelope or some odd scrap of paper, though always ready to break off and offer a genial welcome to one of his friends. On committees or councils he was singularly reticent, rarely venturing a suggestion unless appealed to, but the regularity of his attendance testified to the keen interest he took in the management of business. He was a Commissioner for the Queensland Section of the Colonial and Indian Exhibition held in London in 1886; and was nominated to represent the Australian Colonies at the Washington Prime Meridian Conference in 1884, but was unable to accept the position.

Sir James Cockle died at his London residence on Sunday, 1895 January 27. He leaves a widow and eight children.

AUGUSTUS S. HARRISON, son of Lieut. John Harrison, R.N., was born at Compton, Sussex, in 1824 August. He was educated at Christ's Hospital, London, for eleven years, where he was Senior Grecian and Mathematical Medallist. He entered Caius College, Cambridge, in 1843, and was elected a Scholar in 1844. He took the college Mathematical Prize in 1844 and 1845, and graduated as twenty-seventh Wrangler, with a third-class honours in Classics.

In 1848 he joined the Bengal Educational Department, but after serving in various positions in the Lower Provinces he resigned the service in 1862, and travelled in the hills. Five years later he rejoined the service in the North-West Provinces, and was appointed Professor of English Literature in the Bareilly College. On the institution of the Muir College in 1872, he was appointed its Principal. In 1879 he came under the age rules, but was granted an extension of service, which was renewed in 1884. Mr. Harrison was not only a mathematician and a man of science, but a Sanskrit scholar and widely read in literature. Though absent from Europe continuously for forty years, he kept well abreast of the progress of mathematical and physical science. He died very suddenly of fever on 1885 June 22, at Allahabad, though his death has only recently become known to the Society.

He was elected a Fellow on 1876 January 14, but contributed no papers to the Society.

BENJAMIN JOHN HOPKINS was born at Haggerston in 1862 October. His father was a journeyman carpenter and joiner, but gave up this trade some years later to take a small beer-house, in the neighbourhood of Hornsey. The son received an indifferent education at various local schools, and at the early age of ten years was kept at home to act as potboy. With the exception of another year's schooling in 1874–5, when his father had disposed of the beerhouse at Hornsey and not yet taken another, and of a few weeks' instruction at odd times, Mr. Hopkins was self-taught. His enthusiasm for science was, however, conspicuous even at this early age, and during this last year he applied himself with such diligence to the study of sound, light, and heat as to gain the certificate of the Science and Art Department in these subjects as well as for drawing and geometry. In 1875 his father took another beerhouse, "The Dog and Gun," at Canning Town, and having an invalid wife and no other children, kept his son at home to serve behind the bar. The boy now began to take an interest in astronomy, purchasing books at secondhand bookstalls with such pence as he could save from his dinner-money. His parents gave him a pocket telescope, and he managed later to purchase an old quadrant for 3*s.* 2*d.* after hard bargaining with a Jew dealer. He read his books behind the bar when business was quiet in the afternoons, and made observations in the backyard at all hours of the night. In 1876 (when only fourteen) he conceived the idea that the

rotation of comets' tails at perihelion was a phenomenon of the same nature as the rotation of the radiometer (then believed to depend on the action of light): he wondered whether the light of the Sun might not act as a repelling force on the matter composing the tail, and wrote to the President of the Royal Society (Sir Joseph Hooker), making the suggestion. Professor Stokes, to whom the letter was referred, replied at some length not only to this but to several other queries of the young enthusiast, and ultimately went to see him in 1876 December, and further recommended him to Lord Lindsay, who also visited the "Dog and Gun" to see the astronomer behind the bar. This latter visit resulted in an invitation to Dunecht, where young Hopkins spent a delightful month among instruments such as he had dreamed of, returning home with a 1½-inch telescope, with which all his subsequent observations were made up to 1882, including that of the transit of *Mercury* in 1878. He communicated these observations to the *English Mechanic*, and afterwards wrote various letters to that journal, the most important being one describing a proposed instrument for determining the colours of stars.

He was now apprenticed to a brass engraver, and his hours of work were very long. In 1883 his mother died. In 1884 he married; in 1886 he tried, without success, to establish himself in business in the City, and passed through a time of trying poverty and reverses, happily, however, not of long duration. His interest in astronomy never flagged. He had already commenced a book on "Astronomy for Every Day Readers; suitable to be taken up by the mechanic at the close of a laborious day's work, or by the tradesman after a harassing day spent in competing with his rivals," and continued his writing throughout this period of poverty. From difficulties in finding a publisher this book did not appear till 1893; from it most particulars in this notice have been taken.

Mr. Hopkins was elected a Fellow in 1883 April. He communicated three papers to the Society, one on the Great Comet of 1882, and two on "Erratic Meteors," meteors, that is, with apparently broken paths; all three were accompanied by drawings. He wrote several papers in the *Astronomical Register*, the *Observatory*, *Nature*, *Knowledge*, and the *English Mechanic*, and as a member of the British Astronomical Association contributed frequently to its journal.

His health was never good, and he died on 1894 January 16, at the early age of 32. He leaves an invalid widow and two little girls in very poor circumstances.

RICHARD JOHNSON was born at Dublin on 1840 March 22. He obtained a classical scholarship at Trinity College, Dublin, in 1867, but afterwards devoted himself to the teaching of experimental science with considerable success. He remained at this college, unmarried, till his death on 1894 February 6,

and his rooms in college were a regular centre of attraction to his friends and former pupils. He was devoted to athletic exercises, and especially to cycling.

He was one of the observers in the Transit of *Venus* Expedition, 1874, occupying the station of Waimea, in the Sandwich Islands, and his successful observations show him to have possessed considerable astronomical knowledge.

He was elected a Fellow on 1874 May 8, but contributed no papers to the Society.

GEORGE KNOTT was born on 1835 October 30, and was the only son of George Knott, Esq., of Bohun Lodge, East Barnet, a well-known connoisseur of pictures, who died in 1844. At nearly the same time our late Fellow lost his mother. His early education was conducted by private tuition, but he spent two years at University College, London, and graduated at London University (B.A. in 1856, LL.B. in 1857), in the affairs of which he always took a lively interest. On attaining his majority, and coming into a sufficient fortune, he settled at Cuckfield in Sussex, and married in 1859. Here he spent a life chiefly devoted to astronomy, until the time of his death, which occurred very suddenly in October last. An accidental chill developed into pleurisy on Monday, October 1, into inflammation of the lungs on the following Friday, and on Monday, October 8, he died. He leaves a widow, but no family.

Mr. Knott's life was devoted mainly to astronomy, though he kept himself acquainted with cognate sciences and rendered unobtrusive aid to benevolent and religious institutions. His interest in his favourite science was early awakened by the late Dr. Drew, F.R.A.S., of Southampton, and his first telescope was an excellent 4-inch Gregorian reflector which had belonged to his father. In 1859 he purchased a $7\frac{1}{8}$-inch equatorial and a transit circle, and commenced systematic observations of double and variable stars and planets with the former, and of various objects with the latter; but after a short time observations with the meridian instrument were restricted almost entirely to tran sits of the Sun for clock error. The observations of variables were maintained with marvellous regularity and continuity through most of the thirty-four years of Mr. Knott's working life, and his double-star observations until 1873, when he removed from his residence, Woodcroft, and built himself a new house with observatory attached, as near as possible to his old home. The building occupied a year or two, during which he lived in a smaller dwelling, and was practically cut off from observing; and this interval he employed in arranging for press his double-star observations, which were accordingly printed in vol. xliii. of our *Memoirs*. The year 1875 saw the telescope and transit re-erected at the new house, Knowles Lodge, and the interrupted watch on variable stars was resumed; but no serious work on double stars was again under-

taken, though a few experimental measures (chiefly for personality) are recorded. All the observations are entered with the most scrupulous neatness in a journal, and transferred to ledgers. For the variable stars there are twenty-three such ledgers, each devoted to an individual star, all of which could be put directly into the printer's hands.

A continuous series of observations of this kind, by the same observer, and with the same instrument on the same plan, is probably unique. This unswerving devotion to a particular line of research, which is at least exceptional in the case of those who work at astronomy for amusement, is the more remarkable when we remember that Mr. Knott saw the introduction of the spectroscope and of the photographic plate without being tempted away from his chosen work. And yet this persistence was far from being intolerant. So far as the spectroscope would help the particular work he was engaged on, Mr. Knott welcomed it; and notes on the spectra of the variables occur in many places in the "Remarks" to his observations. Had his time not been fully employed with the eye-observations, he would doubtless also have supplemented them by photographic observations; but as it was, the undoubted fascinations of new methods were resolutely neglected in the interests of continuity.

This note would be incomplete without a reference to the excellent astronomical library collected by Mr. Knott.

From a series of letters from the Rev. W. R. Dawes to Mr. Knott during the years 1857–1866, which have been carefully preserved, several interesting facts are made apparent. It was through Mr. Dawes that Mr. Knott obtained his telescope, and the first letter (dated 1857 September 17), obviously in reply to the first inquiries on this subject, reminds us in a striking manner of the instrumental progress made since that time. "I do not know," says Mr. Dawes, "of any large object-glass fit for your purpose to be had at present. The 8-inch I have now in use would no doubt suit you exactly, but it is already disposed of. . . . Mr. Alvan Clark, of Boston, who made it, is now constructing for me a telescope of shorter focus and a complete equatorial mounting. In the meanwhile, as my Munich equatorial mounting will be deprived of the telescope it at present carries, I have requested Clark to send me a 7-inch glass in tube &c. to fit the mounting, and if a friend of Admiral Smyth's, to whom I have promised the first offer of it, should decline it, the whole may be at your service if it would suit you."

This was the telescope which Mr. Knott ultimately obtained, and the correspondence thus opened continued with great regularity to the time of Mr. Dawes' death in 1866. The two enthusiastic observers constantly interchanged notes on their observations—chiefly about double stars. Though he had done excellent work in stellar photometry, Mr. Dawes apparently did not share Mr. Knott's affection for the variables. In 1863 October he writes: "I am heartily glad that you have not relin-

quished double-star measuring, for which, as you justly say, your O.G. is so admirably suited. Indeed, you will not wonder that, as I consider you to possess in a very high degree the essential qualities of an accurate observer of these objects, I have felt not a little jealous of such a telescope and such an observer being mainly employed on variable stars, on which, to say nothing of the observer, a vastly inferior telescope would do as well." Thus the choice of his particular line of work was entirely Mr. Knott's own, for certainly no other astronomer exercised the same influence on his work as did Mr. Dawes. In later years he corresponded chiefly with other variable-star observers (Baxendell, Birmingham, Espin, Gore, E. C. Pickering, Webb, Yendell and others) about their common difficulties. Many of these letters, too, are of interest.

It only remains to add that Mrs. Knott has not only placed these observations and letters at the disposal of the Society, but has signified her desire to contribute in a most generous manner towards the expenses of publication of the observations. Mr. Knott wrote during his lifetime more than 30 short papers, besides the double-star memoir above mentioned, but the greater part of the variable-star observations will be published for the first time.

Mr. Knott was proposed by Mr. Dawes and elected a Fellow of this Society on 1860 November 9. It is noteworthy that at this time the two friends who had corresponded so intimately had never met. It is plain from the letters that several urgent invitations were exchanged, but to no purpose until some years later. This devotion did not, however, prevent Mr. Knott from attending the meetings of this Society with the greatest regularity, although each visit entailed a midnight drive of two miles on his return to Cuckfield. He was elected on the Council first in 1868, and was a member of it with few interruptions from that time onwards.

James Leigh was born at Liverpool on 1838 June 1. His professional career as a banker commenced at Liverpool, and after being for some years at Warrington he removed in 1873 to Birmingham, and from 1876 to the time of his death was manager of the Metropolitan Bank of England and Wales. He married in 1863, and leaves two daughters and a son.

He was thoroughly engrossed in his work, and was rewarded by considerable success; his unsparing devotion unfortunately hastened his death. He rarely took part in public affairs, though he occasionally wrote to the Press on financial matters. His spare time was chiefly given to the study of natural science, especially astronomy, entomology, and ornithology. His most active period of astronomical work was in the years 1863–73, when he resided first at Rockferry, Cheshire, and afterwards at Penketh, Lancashire; and he regularly and systematically observed the Moon, noting occultations and taking micrometrical measurements of lunar craters and of double stars with an

8-inch reflector and a 4-inch refractor by Cooke, of York. His intention to resume astronomical work in 1882 was frustrated by an attack of rheumatic fever, and he was compelled to limit himself to indoor work with the microscope.

He was elected a Fellow on 1882 March 10, but contributed no papers to the Society.

JOHN MORGAN was born at Gretna on 1809 December 7. He was the younger son of the Rev. John Morgan, minister of the parish of Gretna, Dumfriesshire. In early life he went to Cartagena, in South America, and afterwards spent some years in business in Trinidad, returning with a modest fortune in 1842. Very shortly after, he came to reside at Springfield House, Bishopbriggs, with his brother William Morgan, an East India merchant, who died in 1856. Unmarried and of a retiring disposition, Mr. John Morgan lived in quiet seclusion at Springfield till his death, which took place on 1894 May 4.

ARTHUR COWPER RANYARD was born at Swanscombe, in the county of Kent, on 1845 June 21, and, after his father's removal to 13 Hunter Street, Brunswick Square, he was educated at University College School, Gower Street. On leaving the school he entered the adjoining college, where, from the influence of the late Professor De Morgan, whose classes he attended, he acquired a strong love for mathematics and astronomy. Whilst at University College he collaborated with Mr. George De Morgan in founding a "Students' Mathematical Society," which had a most successful career, developing eventually into the present "London Mathematical Society." Mr. Ranyard read the first paper before the new society, one "On Determinants."

From University College, London, Mr. Ranyard went to Cambridge, entering on residence at Pembroke College in the October term of 1865, and taking his degree in 1868. Three years later he was called to the Bar at Lincoln's Inn, but, whilst adopting the law as his profession, his leisure hours were mostly devoted to science. Thus he joined the Physical Society in its first session, and in 1872 worked with Lord Lindsay (the present Earl of Crawford) in the study of photographic irradiation. Again in 1885 and 1886 the same subject of photography occupied his attention, and he conducted a number of experiments in order to determine the relations between the length of exposure and the intensity of photographic action.

His connection with Lincoln's Inn gave scope for the exercise of another side of his character, his interest in relics of the past. The preservation of ancient monuments appealed strongly to him, and he took a great part in saving the old gateway of Lincoln's Inn from destruction, and also the houses in "Old Buildings," including Lord Thurlow's chambers. In the latter he was especially interested, as the character of Cromwell himself, and

the incidents of the Cromwellian *régime* had been a favourite subject of study with him.

His chief work as an astronomical observer consisted in his observations of the three total solar eclipses of 1872, 1878, and 1882. On the first occasion he was one of the observers sent out by the Joint Committee of the Royal and Royal Astronomical Societies, and was stationed at Villasmunda, near Augusta, Sicily. He was here favoured with much better fortune than awaited most of his colleagues, and was afforded a fine view of the phenomena of totality. The observations assigned to him were polariscopic, and he carried them out with entire success, repeating, with a few additional details, those made by Prazmowski in 1860. His expeditions to America to view the total solar eclipse of 1878, and to Egypt to view that of 1882, were made at his own expense, and he went on his own responsibility. He was contemplating an important work in the department of solar physics on the lines opened up by M. Deslandres and Professor Hale, when the disease which afterwards proved fatal laid its hand upon him. He had had a spectroheliograph constructed for him, and this he lent to Professor Hale for the latter's expedition to Etna to attempt the photographing of the corona in full sunshine. Mr. Ranyard never had the opportunity of using the instrument himself, and it lay in its cases, not yet unpacked, at the time of his death. He willed it, together with the Calver reflecting telescope, for which it was designed, to Mr. J. Evershed, a Fellow of this Society.

Mr. R. A. Proctor's sudden death in 1887 left the publication of his great work, *Old and New Astronomy*, in a most unfinished state, and his magazine, *Knowledge*, without an editor. It was exceedingly typical of Mr. Ranyard's generous spirit that he cheerfully undertook the immense amount of hard work, extending over many months, which the completion of the *Old and New Astronomy* involved, in order to sustain the reputation of his deceased friend and to assist his family. And difficult as it was to follow a man of Proctor's ability, and to sustain his work upon an equal level, Mr. Ranyard fully succeeded in the task.

The subjects which he chiefly discussed in these two publications were: the conditions of the various envelopes of the Sun, the structure of the solar corona, the structure and dimensions of the stellar universe, the distance of the Milky Way, and the density of nebulæ, of the great *Orion* nebula in particular. The especial feature which he introduced into *Knowledge* was the reproduction of a number of important astronomical photographs, a feature very gratefully welcomed by many astronomical amateurs. He devoted also considerable space to the reproduction of photographs of lightning and to the discussion of the phenomena of "ribbon flashes" and "dark flashes."

Another publication undertaken by Mr. Ranyard was that of Professor De Morgan's little brochure, *Sir Isaac Newton, his Friend, and his Niece*, to which he supplied a preface. Nor

was the reputation of Sir Isaac Newton the only one in which he was interested. He was anxious that the gifted young pioneer of English astronomy should have due honour rendered to him, and was instrumental in having a memorial tablet erected to Jeremiah Horrox in Westminster Abbey.

He took an active part in public affairs and was very earnest in promoting the establishment of the St. Giles's Public Library, of which he was one of the Commissioners. He consented to stand as one of the candidates for the Holborn Division in the County Council election of 1892. His good temper and evident straightforwardness and honesty made the most favourable impression on the electors, and he and his colleague, Mr. Remnant, were the only two candidates of their party who succeeded in winning seats from their opponents at that election. Many of his friends feared that he was thus taking a burden upon him too heavy for his strength, knowing the thorough conscientiousness with which he discharged every duty that he undertook. Thus, in the year ending March, 1893, he had attended every meeting of the County Council, and almost every meeting of the committees on which he was serving. Of these the one in which he effected the most important work was the Building Acts Committee, especially in connection with the New (London) Building Act, with reference to which he gave evidence before a Select Committee of the House of Commons.

His connection with the Royal Astronomical Society began at an unusually early age, he having been elected a Fellow when only 18. His first work in an official capacity was in the preparation and organisation of the Eclipse Expedition of 1870; Mr. J. Norman Lockyer being appointed Secretary of the Joint Eclipse Committee of the Royal and Royal Astronomical Societies, and Mr. Ranyard, Assistant-Secretary. He was elected to a seat on the Council in February, 1872, and to the Secretaryship in February, 1874. This office, which he retained till 1880, he filled with conspicuous industry and courtesy. During his tenure of this office he brought out vol. xli. of the *Memoirs*, the great "Eclipse" volume. In its inception it was intended to be a report of the eclipses of 1860 and 1870, and at first Mr. Ranyard worked with the assistance and under the oversight of Sir G. B. Airy, then Astronomer Royal. Soon, however, the entire work devolved upon him, and its scope was extended until it embraced the collation and arrangement of the known observations of all eclipses down to 1878. This work, most admirably designed, and most laborious in execution, was not published until 1879.

Including the years of his secretariate, he sat nineteen years upon the Council.

Early in the summer of 1894 a mysterious loss of weight and other disquieting symptoms began to make themselves apparent. These were eventually traced to the formation of an internal cancer which all but precluded the possibility of nourishment

entering the system. After a long and most trying illness, borne with great patience and hopefulness, he died on December 14, 1894, whilst the meeting of the Royal Astronomical Society, in the welfare of which he took from first to last so keen an interest, was in session. Mr. Ranyard was not married, and only one of his immediate relatives, a brother in Australia, survived him. But his purity of motive, his generous spirit, his freedom from self-seeking, and his unfailing courtesy of manner, endeared him to a large circle of friends who will keenly feel his loss. Amongst these will be numbered not a few of the most distinguished foreign astronomers, Mr. Ranyard having been an excellent linguist, and frequently visiting the Continent. He was elected a Fellow of the Society 1863 November 13.

Henry Roe was born at Corfe Castle, Dorset, on 1833 October 22. At the age of nineteen he became tutor and Government Lecturer in Mathematics at the Metropolitan Training Institute, Highbury, and held this office till 1865, when he took Orders and was appointed to the Head Mastership of Kineton Middle School, and the Curacy of Combroke. While holding these offices he became Evening Lecturer at Tysoe (1869–75), and then for a short time Chaplain of Chadshunt. In 1876 he was presented to Poyntington and made Chaplain of the Sherborne Union, and was for seven years (1877–84) also Assistant Diocesan Inspector. He remained at Poyntington for twelve years, for the last eight of which he was Curate of Sherborne. In 1883 he became Rural Dean of Merston; in 1884 Diocesan Inspector for the Archdeaconry of Taunton, and the Rural Deaneries of Merston, Ilchester, and Paulet; and in 1886 he was made Prebendary of Ilton in Wells Cathedral. He was appointed to Yeovilton in 1888 by the Bishop of the diocese.

Prebendary Roe was on the General Committee of the Exeter Congress and a member of the small but very important "Subjects Committee." He married in 1858 and leaves two sons and two daughters. He died at Yeovilton Rectory on 1894 September 16 after a four days' illness, and his widow only survived him by seventeen days.

He was elected a Fellow on 1864 February 12, but contributed no papers to the Society.

William Tomlinson was born at Ilkley, Yorkshire, on 1809 December 4. In 1846 he became a master in the Royal School of St. Peter at York, where he was subsequently placed at the head of the Civil and Military Department. This post he retained until his resignation in 1873. In 1882 he left York for the milder climate of Sandown, Isle of Wight, where he died, 1894 January 17.

Mr. Tomlinson attained a considerable reputation as a successful and enthusiastic schoolmaster throughout the country. He was an able mathematician and an ardent lover of the natural

sciences. His health was remarkably good, and to the last he retained his faculties, his powerful analytical mind losing nothing of its acuteness.

He was elected a Fellow on 1855 January 12, but contributed no papers to the Society.

GEORGE WALL was born 1820 December 20, in the neighbourhood of Manchester. He was educated at home, and on account of his weak health he went out to Ceylon in 1846, and founded, in 1854, the firm of George Wall & Co., Coffee Merchants and Estate Agents, in Colombo. In 1856–57 he filled the office of Chairman of the Planters' Association, and in 1858 was elected Planting Member of the Legislative Council. He returned to England in 1859, and till 1863 was partner in the firm of Sir Joseph Whitworth & Co., Manchester, and took a leading part in the manufacture and testing of their small arms, which created so profound a sensation in military circles at that time. Mr. Wall again went to Ceylon in 1863, and in 1866 was elected Chairman of the Chamber of Commerce; he came back to England in 1868 as delegate representing the Colony in the Parliamentary inquiry into the affairs of Ceylon, and on his return was again Chairman of the Chamber of Commerce, from 1874 to 1879.

Up to this time Mr. Wall had a good observatory at each of his two residences, and devoted much time and expense to astronomical studies. But in 1879 the firm of George Wall & Co. failed, chiefly through the devastation of the coffee crops by blight, and from this time his more reduced circumstances, as well as failing eyesight, prevented his further pursuit of astronomy.

In 1892 the Cobden Club awarded their gold medal to Mr. Wall for his services in connection with the abolition of the Ceylon Grain Tax. He was twice married, and leaves a widow and thirteen children. He died 1894 December 18.

Mr. Wall was a Fellow of the Linnean Society, and was elected a Fellow of the Royal Astronomical Society 1872 February 9. He was the author of several books, including an abstruse work entitled "The Natural History of Thought."

Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the Directors of the several observatories, who are alone responsible for the same :—

Royal Observatory, Greenwich.

Notwithstanding the cloudy weather which prevailed through a great part of the year, the large number of observations made with the transit-circle in 1893 has been equalled in 1894 ; the total number of transits observed during the year being 10884, and of meridian zenith distances 10694. The total number of stars observed with the transit-circle during the year is 3057.

The mean error in R.A. of Hansen's Lunar Tables with Newcomb's Corrections, as deduced from 101 observations with the transit-circle is $-0^s.019$. For the years 1883 to 1893 the errors are $+0^s.032$, $+0^s.021$, $+0^s.028$, $+0^s.029$, $+0^s.068$, $+0^s.079$, $+0^s.010$, $+0^s.020$, $+0^s.079$, $+0^s.069$, and $+0^s.036$.

The apparent correction to nadir observations deduced from reflexion observations of stars ranges from $0''.00$ to $-0''.50$ for the several months of the year. The mean correction for the year is $-0''.271$, which agrees with the results for 1892 and 1893. For the years 1890 to 1894 the corrections are $+0''.08$, $+0''.07$, $-0''.25$, $-0''.34$, and $-0''.27$.

The series of observations begun in 1893 in which the direct observation of zenith distance was taken before the reflexion was continued in the early part of 1894, 103 observations having been made. The bearing of these observations (130 in all) on the R—D discordance is discussed by Professor Turner and Mr. Thackeray in a paper which will be published in the *Memoirs of the R.A.S.*, vol. li.

During the year twenty-five determinations of horizontal flexure of the transit-circle were made.

A series of observations was begun in December in which pairs of stars, of nearly the same North Polar distance, and at an interval of 5 or 10 minutes in Right Ascension, were observed in zenith distance, the one directly, and the other by reflexion, alternately on alternate nights. It is hoped, by these means, to obtain further information on the nature of the R—D discordance.

The Moon was observed with the altazimuth in the first and

last quarters as in previous years. Sixty-three observations were made in the year. The building for the new altazimuth or universal transit-circle is in progress, the concrete piers for the instrument and collimators having been erected. The instrument is practically completed and will be mounted as soon as the building is ready.

Three comets were observed during the year with the Sheepshanks' equatorial, namely:

Comet (*a*) 1894 (Denning)	on	6 nights.
„ (*b*) 1894 (Gale)	„	26 „
Encke's Comet	„	3 „

Sixteen occultations of stars by the Moon and twenty-five phenomena of *Jupiter's* satellites were observed with the equatorials by one or more observers. No observations of the transit of *Mercury* were made on November 10 owing to clouds.

The observatory has received from Sir H. Thompson a valuable gift of 5000*l.* to provide a large photographic telescope of 26 inches aperture and 22 feet 6 inches focal length with accessories, which would serve as the complement of the 28-inch visual telescope. This telescope, which is being made by Sir H. Grubb, will be of exactly double the dimensions (aperture and focal length) of the astrographic equatorial, which has proved so successful, and will be mounted on a very firm stand which will allow of complete circumpolar motion, without the necessity for reversal on the meridian. It will be erected on the central tower of the new Physical Observatory, under the 30-feet dome. The south wing of the new Physical Observatory was completed on April 30, and has been occupied since the beginning of June. The building of the north wing and completion of the central octagon was begun in September, so that the building will soon be ready for the erection of the dome.

With the 28-inch refractor three different kinds of observations have been made.

(1) The telescope was adapted to photography by reversing the crown lens and separating the lenses according to the plan proposed by Sir G. G. Stokes. A large number of photographs were taken to determine the best distance between the lenses and the exact adjustment of the crown lens for tilt and centring relatively to the flint. Interesting information was obtained which will be useful in connection with the Thompson 26-inch photographic telescope.

(2) The half-prism spectroscope has been very firmly mounted on the tube of the telescope and parallel to it, two reflecting prisms being employed to bring the light from the telescope on the slit of the spectroscope. The adjustment of the spectroscope to focus and collimation, having to be made step by

step, took a considerable time, and was much hindered by the cloudy weather during the latter half of the year.

(3) The visual observations consist of measures of twenty-one double stars on thirty nights, of the satellites of *Mars* on two nights, sketches of *Mars* on two nights, and of *Jupiter* on one night, of measures of *Jupiter's* equatorial and polar diameters on three nights, and of the diameters of *Jupiter's* third satellite on one night. The measures of diameter of *Jupiter's* satellites are being continued. Attempts were made to measure *Jupiter's* fifth satellite, but the results obtained were discordant.

With the astrographic equatorial 694 plates with 1600 exposures have been taken on 151 nights, and of these 183 have been rejected—viz., 62 fogged, 35 faulty *réseau*, 38 sky cloudy, 15 wrong setting, 5 put wrongly in the carrier, 13 spoiled in development, 8 injured or broken, and 7 for miscellaneous defects. The number of rejections is unusually large.

The shutter of the dome was blown away in the gale of December 22, but fortunately the observer who was in the dome at the time escaped unhurt, and no damage was done to the instrument. The instrument has necessarily been out of use since this date.

The progress made with the photographic mapping of the heavens during the year 1894 is as follows :

	No. of Plates taken.	Successful Plates.
Astrographic Chart (Exposure 40^m)	196	155
Plates for Catalogue (Exposures 6^m, 3^m and 30^s)	401	259
Number of fields photographed for the Chart ...		140
Number of fields photographed for the Catalogue		220
Total number of fields photographed since the commencement of the work for the Chart ...		408
Total number of fields photographed since the commencement of the work for the Catalogue		618

When practicable a trail has been taken each night on a catalogue plate, and during the year 88 plates with trails have been secured.

The following miscellaneous photographs have also been taken :

	No. of Photos.
For adjustment of Equatorial	11
Pleiades	5
Typical Areas	39
Various regions	4
With the enlarger (14 times)	7

Each plate has undergone a preliminary examination to see whether it was generally satisfactory, and whether the adopted

limits of magnitude were approximately reached as inferred from the 20^s exposure, which should give 9th magnitude stars of Argelander's scale.

It was found on the commencement of the measurement of the plates that it was necessary to reject a certain number of partially fogged plates which had previously been passed.

For the measurement of the photographs a glass diaphragm, with two scales at right angles divided to $\frac{1}{20}$th of a millimetre, is placed in the focal plane of the microscope of the astrographic micrometer. The star's image is placed accurately at the intersection of the two scales, and the position of the *réseau* lines relatively to it is read off on the scales by estimation to $\frac{1}{200}$th of a millimetre, *i.e.* 0·001 of a *réseau* interval, or 0″·3, in the heavens. In a note communicated to the Society (*M.N.* 1894 December) an account is given of the measurement and reduction of four overlapping plates. The result of these preliminary measures was considered so far satisfactory that systematic measurement of plates was begun in October and the 6^m and 3^m images of 1535 stars have been measured.

A new duplex micrometer has been arranged in which the overlapping portions of two plates can be measured at the same time. The plates are placed in a frame movable in one direction, and the carrier of one of the plates can be adjusted so that the images of the same star on the two plates are very approximately in the same horizontal line. Two microscopes carried on a horizontal slide move perpendicularly to the direction in which the frame moves, and their distance apart can be so adjusted that when the image of a star on one plate is at the centre of the field of one microscope the image of the same star on the second plate is within $\frac{1}{10}$th of a millimetre of the centre of the field of the second microscope. Much time is thus saved both in looking for stars and in their subsequent identification.

Photographs of the Sun have been taken with the Dallmeyer 4-inch photoheliograph on 177 days, and of these 323 have been selected for preservation, including fourteen photographs with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination.

The Dallmeyer photoheliograph was mounted during the first four months of the year on the new 28-inch refractor, but on April 24 it was transferred to the south wing of the new building in the south ground, upon the terrace roof of which it was mounted, together with the wooden hut which had formerly sheltered it.

Photographs of the Sun have also been taken with the Thompson photoheliograph on 143 days during the year, and of these 235 have been selected for preservation. Observation with the Thompson instrument has been discontinued since 1894 October 15, the progress of the works on the new building interfering with its use. A few photographs have also been taken with a third instrument, the Dallmeyer photoheliograph, No. 4,

which has been prepared for employment at the Madras Observatory, at the request of the Indian Government, by being fitted with a new enlarging lens by Ross and a camera for taking photographs of the Sun 8 inches in diameter. In all, photographs of the Sun have been taken at Greenwich with one or other of the photoheliographs on 219 days during the year. Photographs have also been received from India and Mauritius up to 1894 September 26, leaving only two days, 1893 December 31 and 1894 January 1, for which no photograph is yet available for measurement in the year ending with the date of the last Indian negative received.

The Greenwich photographs have been measured in duplicate up to the end of 1894, and the areas and heliographic positions of the spots and faculæ have been computed. The complete results for 1892 have been printed, and those for 1893 are nearly ready for press, and a portion has already been sent to the printer. The work is, however, exceedingly heavy, from the number, size, and complexity of the groups of spots observed in 1893.

A falling off in the solar activity, as evidenced by Sun spots, has been remarked during 1894,. but though several fine disturbances have been recorded, particularly that of the latter part of 1894 February, and the Sun has never been without at least three or four distinct groups of spots, there has been nothing to fully equal the displays of 1893 August and December.

The reduction of the Greenwich—Waterville—Hazel Hill—Montreal longitude determination has been delayed owing to an apparent discordance between the first and fourth stages of the results for Waterville—Hazel Hill, which was eventually traced to a misapprehension in the numeration of the seconds at Hazel Hill. The final results will now be given shortly.

Transit observations have been made on six nights at contiguous stations in the front court to determine the difference of longitude between them with the same instruments as were used in the Paris—Greenwich longitude determinations. The results, as far as they go, confirm those obtained in 1893, and are unfavourable to the existence of any anomalous difference of longitude. More observations will, however, be made as circumstances permit.

Mr. Plummer, the Director of the Bidston Observatory, in the course of a determination of the longitude of Bidston, was at Greenwich from January 1–9 and from April 21 to May 1 for the purpose of comparing his personal equation with that of the standard observer at Greenwich.

The volume of Greenwich Observations for 1892 has been printed, and is in the binder's hands. The printing of the volume for 1893 is advancing.

An event occurred in the year which might have done serious damage, a bomb having been exploded on February 15 close to the Observatory by an Anarchist, who was killed by it.

Mr. Turner resigned his position as Chief Assistant on February 28 to take up his appointment as Savilian Professor of Astronomy at Oxford, and was succeeded by Mr. Dyson on March 1. The clerk, Mr. Le Brun, found himself compelled by ill-health to resign on March 19. From April 2 Mr. Cass from the department of the Accountant-General of the Navy, carried on temporarily the cash and clerical duties till May 21, when Mr. H. Outhwaite from the Admiralty was appointed as clerk. There are still two vacancies among the Second Class Assistants.

Royal Observatory, Edinburgh.

The close of the year 1894 saw the buildings of the new Royal Observatory quite finished as far as regards the outside. The most prominent features are decidedly the two cylindrical domes. These were erected by Sir Howard Grubb in such good time last summer, that it was possible to overlay them with copper and complete the tasteful ornamentation before the winter set in. The copper work was entrusted to Messrs. Ewart, of London. When the domes were completely finished the copper was washed down with a saline solution to hasten the uniform colouring of the metal. The green tint thus produced in a few days has added considerably to the appearance of these structures, which have excited general admiration for their elegant and imposing appearance.

Several months must elapse before all the rooms of the observatory are ready for occupation. The domes have still to be fitted with storm shutters and apparatus for opening and closing the roof. The storm-shutters, by partly closing the side opening from below, are designed to screen the observer and the instrument from the more violent winds which so often seriously interfere with the efficient use of a large telescope. The piers are ready for the stands of the two equatorials which will be erected in the early part of the summer. The library, which is shelved for about twenty thousand volumes, is ready to receive the books. These will be provisionally arranged as soon as the warming apparatus is in working order. The transit house has proved a heavy piece of work, owing to the novelty of the plans; but a few months, it is hoped, will see the transit-circle in position.

During the month of November all the instruments and books that still remained at Dunecht were removed to Edinburgh, some seventy tons in all. These are now being gradually unpacked as space becomes available for them. The Siderostat has been adapted to the latitude of the new observatory, the new angle-block having been cast, and the other necessary alterations carried out, by Messrs. Dove & Co. of this city. This and other instruments at Blackford Hill have been under the

charge of Mr. A. J. Ramsay, who has secured a series of photographs showing the progress of the buildings.

The gate-lodge has been occupied for some weeks by the caretaker, and the dwelling-houses for the director and staff will be ready for occupation by the end of April.

At the Calton Hill the arrangements for time signalling by ball and gun have been the same as in former years, and it is intended to continue the present service until everything is ready for transferring the work to Blackford Hill.

During the year the new reduction of the early Edinburgh transit observations has made steady progress in the hand of Mr. Heath, the instrumental errors in 1834–5 having been completely deduced afresh. The individual right ascensions for this period are for the greater part computed, the published mean wire results having been first compared with the original note-books.

A few additional observations for latitude have been made with the mural circle and partly reduced.

A bi-filar pendulum, designed to show tilts of the foundation on which it is placed, was temporarily erected on the rock at Calton Hill, on March 24, at the request of M. Antoine d'Abbadie, who provided the instrument. It was constructed by Mr. Horace Darwin, on the principle suggested by Lord Kelvin. Daily observations have since been made at Paris mean noon, simultaneously with the readings of M. d'Abbadie's nadirane, at Abbadia in the South of France. A copy of the observations made up to December 31 has been sent to M. d'Abbadie, but it is evident that only a continuous photographic record will bring out the full capabilities of the instrument.

Three circulars referring to comets—Denning, Gale, and E. Swift respectively—were issued in the course of the year.

Royal Observatory, Cape of Good Hope.

The reduction of the staff, created by the illness of Mr. George Maclear since 1892 April, and his subsequent retirement in 1893 June, has been the subject of official correspondence, but the post has not yet been filled; besides this, one member of the staff has been seriously ill for two months, and thus the work of the observatory has been still further crippled. Meridian observations have been resumed, but they have been restricted in number to those absolutely necessary for completing the observing list of stars to be contained in the general catalogue for 1890. Observations of the *Sun*, *Mercury*, and *Venus* have not been resumed. H.M. Astronomer regrets the necessity for adopting this policy, but there remains for him only the choice of adding to the already large stock of unreduced and undiscussed observations, or of limiting the work in some such way till an adequate staff is provided.

With the transit-circle there have been made :

Transit Observations	4818
Observations of Declination	5063
Determinations of Collimation	96
„ Level	292
„ Azimuth	293
„ Run	279
„ Nadir	265
„ Flexure	46

The following occultations of stars by the Moon were observed :

Disappearances at the dark limb	7
Reappearances „ „	10
No. of separate phenomena	17

With the zenith telescope 512 observations have been made for aberration and change of latitude.

With the 7-inch equatorial the following comets have been observed :

Gale's	Comet		on 15 nights
Tempel's	„	1873 II.	„ 5 „

With the photographic telescope the following work has been accomplished :

	No. of plates Exposed.	Exposures. No.	Duration.
Catalogue plates	563	1689	6^m, 3^m, 20^s
Chart „	253	253	up to 1 hour
Kapteyn-Pritchard areas	81	243	6^m, 3^m, 20^s
South Polar area	4	12	6^m, 3^m, 20^s
Comparison of areas in various galactic latitudes }	7	14	20^m
Trails for speed of plates, adjustments, &c. }	6	—	—
η Argûs	1	9	total 25 hours

For investigating form and period of light-curve of new variable star in Vela (Gould, 13052) :

Jan. 25 to April 1 (normal mag.)	37	39	6^m, 3^m, 20
Feb. 1 (varying mag.)... ...	4	21	6^m, 3^m, 20^s
7 „	9	81	6^m, 3^m, 20^s
13 „	8	63	6^m, 3^m, 20^s
Apr. 13 „	7	109	6^m, 3^m, 20^s
19 „	4	25	6^m —
25 „	5	39	6^m —
Dec. 12 „	4	16	6^m —
18 „	3	15	6^m —
30 „	1	21	6^m —
	799	2649	

At the Cape, the programme of the International Astrophotographic Congress has been realised to the following extent. After rejecting all plates of insufficient exposure, poor images or which are otherwise faulty, only 70 of the Catalogue plates, out of 1632 areas allotted to the Cape, remain to be done. Of the Chart plates, 263 have been passed as satisfactory.

Two sets of overlapping plates extending over the area covered by the *Victoria* Comparison Stars have been measured by two independent observers for the purpose of determining the optical distortion of the field, and other constants necessary for the reduction of the Catalogue Plates.

The diameters of the discs of the Variable Star in Vela, together with those of nine comparison stars, have been measured for all plates taken up to the end of April. The results show that the star is a variable of the Algol type, its period being about $5^d\ 22^h\ 24^m\ 4^s$. The star's variability was discovered by Mr. C. Ray Woods from a comparison of plates taken on 1893 March 18 and 1894 January 20. A complete discussion of the period will shortly be undertaken.

The state of the printing and reduction of Meridian Observations is as follows :

The Cape *General Catalogue* for 1885·0, with an Introduction, including a discussion of the Latitudes and Refraction Corrections at Greenwich and the Cape, and with an appendix containing a fundamental catalogue of circumpolar stars, has been passed through the press, and is now in the hands of the binders.

The *Meridian Observations* 1885–87, with Introduction, have been passed through the press, and some printed copies were received at the Cape on November 22.

The MS. of results of Meridian Observations 1888–89 was sent to the printer on October 17.

The Meridian Observations 1890–91 are ready for the printer.

The computations of	Mean	R.A.	are complete to	1894	July 20.
,, ,,	,,	N.P.D.	,,	,,	Sept. 21.
,, ,,	Apparent	R.A.	,,	,,	Dec. 2.
,, ,,	,,	N.P.D.	,,	,,	Dec. 15.

The results of Meridian Observations of 480 Southern Fundamental Stars from 1885 to 1894 June have been communicated to Professor Auwers.

The observations of comets are reduced and the results have been communicated to the *Astronomische Nachrichten*. Meridian Observations of all the comparison stars were secured towards the end of the year, but they are not yet fully reduced.

The discussion of the Heliometer Triangulation of the *Victoria* Comparison Stars, and the details of the Heliometer Observations of *Victoria* and *Sappho*, have been passed through the press.

The preliminary discussion of the observations of *Victoria*, leading to the discovery of an error in the hitherto adopted value of the lunar equation, has been passed through press. The MS. of the definitive discussion of the observations of *Victoria*, based on the new ephemeris referred to in last Report, was forwarded to the printers on December 12. A photographic copy of this manuscript has been sent to Prof. Simon Newcomb.

The MS. of the Cape *Photographic Durchmusterung*, vol. i., was forwarded to the printers on June 19; the definitive specimen page was finally settled, and the work of printing put in hand on October 10.

It has still remained impossible with the inadequate computing force of the observatory to attempt the reduction of the Heliometer observations for stellar parallax, the observations of the mutual distances and position-angles of *Jupiter's* satellites, the zenith-telescope observations, the measures of *réseaux* and photographic plates, and the reduction of the occultations observed since 1881.

The reduction of the meridian observations of the Sun, Moon, and fundamental stars made under the direction of Sir Thomas Maclear, 1861–70, has been commenced.

The printing of the results of the Geodetic Survey has been entrusted to the Cape Government printers. The work is of a character to which they are unaccustomed, and makes slow progress; 160 pages (less than half of the whole) have been passed through the press during the year.

A noble offer has been made by Mr. Frank McClean, viz. to present to the Cape Observatory a large refractor equipped for photographic and spectroscopic work. The photographic telescope to have an aperture of 24 inches and 22½ feet focal length, and be provided with an objective prism of the same aperture, having a refracting angle of 7½ degrees; the visual telescope, to be mounted parallel to the photographic telescope, 18 inches aperture, and the same focal length as the photographic telescope. The equatorial mounting will have complete circumpolar motion for 30° within the zenith, and be sufficiently elevated to allow use of a fair-sized spectroscope suitable for determining stellar motions in the line of sight. Such a spectroscope will be provided, as also an observatory of light construction. The instrument has been for some time under construction by Sir Howard Grubb. The Lords Commissioners of the Admiralty have accepted, with warm appreciation of Mr. McClean's generosity, the offer of this splendid instrument, and have expressed their view that the possession of this instrument will greatly increase the utility of the Cape Observatory, and may be expected to result in considerable advantage to science. Sir Howard Grubb reports that the objective prism is finished, and that a perfect crown disc has been received from M. Mantois for the 24-inch object-glass.

Professor Harold Jacoby, of Columbia College, New York, is at present on a visit to the Cape Observatory. He has devoted

some time to questions connected with the determination of errors of scales and *réseaux*, and has communicated a paper to the *Astronomische Nachrichten* on the subject. At the request of H.M. Astronomer he is undertaking a discussion of the measures of the above-mentioned series of plates of the *Victoria* Comparison Stars.

The time-signal service has been regularly continued. A new time-ball has been erected on an elevated site near the Cape Town Docks, and the fall of the ball is now automatically registered on the chronograph. No error or failure has occurred since the erection of the new ball.

The meteorological observations made at the observatory in 1894 have been communicated for publication to the Cape Meteorological Commission.

The Observatory, Armagh.

During the past year the refractor has chiefly been used for observations of double stars, an endeavour being made to select objects which have not been too frequently observed of late years.

The ingress of *Mercury* on the Sun's disc on November 10 was not seen, owing to a bank of clouds which covered the Sun until about fifteen minutes after internal contact. The planet was then well seen for about six minutes, and appeared as a uniform dark disc without any trace of a halo. The definition was good, notwithstanding the low altitude.

An index catalogue of all the nebulæ found since the publication of the N. G. C. and up to the end of 1894, has recently been sent to the Society. The paper on micrometric measures of nebulæ referred to in last year's report was published in September.

Cambridge Observatory.

The most important part of the work done in this observatory during the year has been the completion of the catalogue of Argelander's stars, which have been observed here in co-operation with the Berlin *Astronomische Gesellschaft*. To facilitate this work an extensive set of tables for calculating the secular variation of the precession in right ascension and declination, supplementary to the tables already calculated for the precessions themselves, was completed on February 10. The mean places for the epoch 1875·0, deduced from each individual observation, are entered in a comprehensive catalogue, which is now complete with the exception of dates and precessions in right ascension for the last four hours. A smaller catalogue, giving the mean places for each star deduced from all the observations of that

star, and arranged to correspond with the other volumes of the series published by the *Astronomische Gesellschaft* is being copied for the press. It is all prepared, and the first seven hours of right ascension are ready to be placed in the hands of the printer.

The transit circle was used on 147 nights, chiefly in observing clock stars, stars for instrumental correction, zone stars which it was thought desirable to re-examine, *Mars* near the opposition, observations for personal equation, and a few for the inclination of the wires, making in all 1456 meridian observations.

The nadir point was observed 121 times, in sixty of which the bisections were made on both the north and south sides of the telescope. The results prove that when the observer stands on the south side of the telescope the nadir point still comes out slightly greater than when on the north side.

The level and collimation were each observed 138 times, and 36 observations were made to obtain coefficient of flexure.

On March 20 the gas was introduced into the transit room, and two incandescent burners were fitted on for illuminating the microscopes, the wires in the transit telescope, and the collimating eye-piece. These burners give a pure white light very comfortable for the observer.

Ninety-five comparisons of Gale's Comet with neighbouring stars were obtained on ten separate nights in May and June with the Northumberland equatorial and square bar micrometer. From those of May 4, May 23, and June 11, a very satisfactory orbit was obtained, which has been published in the *Notices*.

Repeated applications for accurate places of stars have been made during the year. Those included within the limits of our zone were found in the catalogue and forwarded at once; the others have been observed or are in process of observation just now.

The Newall Telescope, Cambridge Observatory.

The Newall telescope has been used for observation on 121 nights in the course of the year 1894, the later part of the year being very unfavourable for observations.

The experimental trials of different prism arrangements for a slit spectroscope for photographic purposes were completed in the spring. On the results of the trials was based a design of a spectroscope, and the instrument itself is now very nearly completed.

The study of the spectrum of α Orionis by photographs was continued in the spring, partly with one objective prism and partly with a direct vision slit spectroscope.

A number of photographs of stars have been taken under different conditions with a view of testing the performance of the

visual object-glass in photographic work, and some of the results are recorded in a paper in the *Monthly Notices*, vol. liv. p. 373. Some peculiar features presented themselves in some of the star images, and further study of them brought to light some interesting results, many of which are embodied in a paper in the *Monthly Notices*, vol. liv. p. 515.

Photographic enlargements of some of the planets have been taken with some promise of greater success. The coarser detail of the Moon is well shown in some enlargements taken with the same enlarging apparatus attached to the telescope.

It seemed best whilst the spectroscope was being made, to desist from further attempts to work with makeshift spectroscopes, and to undertake some micrometrical work. The inner satellite of *Mars* was accordingly observed on all possible occasions in the autumn, and a considerable number of measurements were obtained in spite of very unpropitious weather. The fifth satellite of *Jupiter* has been seen on three occasions in the present opposition, but it has not yet been found possible to measure it.

Dunsink Observatory.

The meridian circle and chronograph have been employed during the year in observing stars with large proper motions on the working list referred to in previous reports, to which early in the year the *Nautical Almanac* list of zodiacal stars was added at the request of Dr. Downing. Of these stars 365 observations of right ascension and 359 of declination have been made.

Since the end of June the necessity of pushing on with the reductions has diminished the number of observations, most of the observations since that date having been made for the purpose of duplication.

As they stand at present, all the observations, with very few exceptions, up to 1894 June have been reduced to mean place, and the work of bringing them up to catalogue form for the epoch 1890 is well in hand. The observations taken in 1889–90–91 in the intervals of other work (some of which had not even been written up from the chronograph sheets and observing notebooks owing to the smallness of the staff at this observatory) have been fully reduced during the year. This work, consisting of the places of over 600 stars, which have been credited with large proper motions, is at present in preparation for the press, and will shortly be published as the seventh part of the *Astronomical Observations and Researches made at Dunsink.*

As in recent years the standard stars of the *Berliner Jahrbuch* have been used for determining the clock corrections and the equator point of the circle, 405 right ascensions, including those of 78 close circumpolar stars for azimuth corrections, and 236 zenith distances of standard stars having been observed.

The level correction has been determined 171 times, the collimation correction 110 times, the nadir point (by reflexion) 92 times, and the correction for run 19 times. A new mercury-trough, with an amalgamated copper bottom on the principle of that used at the Oxford University Observatory, has been provided for observations of the nadir and of the collimation correction.

Very little work has been done with the "Roberts" 15-inch photographic equatorial, and that little consisted chiefly of visual observations for testing the performance of the clock. The difficulty of obtaining uniform motion, to which such frequent reference has been made, still, however, prevailed, notwithstanding some recent alterations; and all attempts at modification having failed, it was finally decided to replace the mounting by one of Sir Howard Grubb's latest patterns, designed specially for photography.

This is now almost completed, and will be an exact *replica* of the mounting which carries the Greenwich 13-inch photographic instrument, up to the cross-head of the declination axis.

A new 18-foot dome for this instrument, consisting of a steel framework, covered with *papier mâché*, and furnished with a wide sector, opening beyond the zenith on Dr. Gill's principle, has been constructed and erected by Sir Howard Grubb during the year.

With the Troughton and Simms microscope 318 measures of photographs were made, mostly of photographs of the Dumbbell Nebula, taken at Mr. Wilson's Observatory in Westmeath. The results of these measures were published in the *Monthly Notices* for 1894 March.

With the "South" equatorial a small number (69) of micrometer observations, consisting generally of from four to six measures of position and a similar number of measures of distance, have been made. These include measures of a few of Otto Struve's double stars of Section II. vol. x. *Observations de Poulkova*; of the discs of *Jupiter* and *Saturn*; of standard distances in the clusters *Præsepe* and *h Persei* to determine the scale value of photographs; and of the position of Gale's Comet with reference to stars in its neighbourhood. The last have been published in the *Astronomische Nachrichten*.

There have also been 236 transits of stars observed with this instrument for determining the temperature correction of the Grubb micrometer.

On March 22 the "South" refractor and the 5-inch guiding telescope of the "Roberts" equatorial were used to observe the occultation of *a Virginis*, the results of which were published in the *Monthly Notices* for April.

The measures of β *Cygni* and γ *Andromedæ*, the results of which are incorporated in a paper in the *Monthly Notices* for 1895 January, "On the Effect of Atmospheric Dispersion on the Position of a Star," have also been made with this instrument.

Preparations were made for observing the transit of *Mercury* on Nov. 10, but clouds prevented anything being seen.

The time service has been maintained as in former years; and on the first Saturday of each month the observatory has been open to visitors, and the 12-inch "South" refractor placed at their disposal.

Glasgow Observatory.

In 1894 March the Trustees of the Bellahouston Bequest Fund made the generous grant of 1000*l.* to the Chair of Astronomy in the University, which is being employed in bringing the instruments at the observatory into efficient working order.

The 6-inch transit circle by Ertel is undergoing extensive alterations in Troughton and Simms' works: new piers have been built and the four old-roof shutters of the transit-room (which were of such a construction as, when opened, to cover half of the effective aperture of the slit) have been replaced by a single shutter, 31 feet in length, and running on pulleys. It is expected that the transit-circle will be ready for work by the beginning of April.

The 22-foot dome which houses the 20-inch "Breadalbane" reflector has been provided with two new shutters, and the Robinson's anemograph, formerly mounted on the top of this dome, has been erected on an iron lattice standard, such as is used for railway signal-posts.

It is noteworthy that the mounting of the reflector, made by Grubb in 1855, is of the same type as that employed for the photographic telescope at Potsdam. Sir Howard Grubb has been engaged in making a new 20-inch silver-on-glass mirror for this instrument. A large rigid platform firmly fixed to the declination axis and to the upper end of the tube will carry the various parts of a slit spectrograph of $3\frac{1}{2}$ inches aperture. One of the 60° prisms, $6\frac{1}{2}$ inches on a side, has already been supplied by Mr. Hilger.

The two sidereal clocks of the observatory have been removed into a large press with double walls, the spaces between which are filled with silicate cotton. In the course of weeks the temperature inside this press undergoes but slight variations, and, besides this, one of the clocks is kept in an air-tight case at a constant pressure of 27·0 inches. Both clocks can be switched to the Fuess chronograph.

It is worth mentioning that our novel mode of central field illumination has been most successfully adapted to the 3-inch transit instrument. The method may be thus described: a direct reflecting prism, $\frac{1}{2}$ inch on a side, is cemented to the outer surface of the object glass, and reflects the light from an electric lamp of 1 candle-power, which is firmly connected with the dew-cap at a distance of about 3 inches from the tube.

The time observations and the extensive meteorological work have been carried on as usual.

Liverpool Observatory.

The Liverpool Observatory exists mainly for the determination of time and its distribution to the Port of Liverpool, the rating and examination of chronometers deposited by makers and shipowners, and the maintenance of the series of meteorological observations. These duties have mainly occupied the attention of the small staff attached to the observatory. An alteration in the regulations made by the Dock Board has materially diminished the number of chronometers submitted for rating. Hitherto this work has been rendered free of charge to all engaged in the trade of the Port, but a small fee is now exacted, and the result has been that only one-half of the number of the marine chronometers usually sent to the Observatory has been deposited during the year.

An inquiry has recently been completed into the diurnal inequality of the barometric pressure as exhibited in the records obtained from the King's barograph, which has been continuously at work since 1867. The inequality has been derived for each month, and exhibits much the same features as those disclosed in the inquiry made at Greenwich from the observations 1854–1873. The general curve for the year can be represented by the expression

$$+0^{m}\cdot0010 \sin(\theta+63^{\circ}) + 0^{m}\cdot0086 \sin(2\theta+138^{\circ}).$$

The diurnal term is something smaller than that found at Greenwich. The angle in the semi-diurnal term indicates that the nodal point is passed about a quarter of an hour later at Liverpool than at Greenwich.

The result of an inquiry into the position of the Observatory has appeared in the *Monthly Notices*.

Attention is given to cometary observations; Denning's comet was observed as frequently as possible, and a fair series of Gale's was secured. These observations have also appeared in the *Notices*.

The courses of lectures on astronomy continue to be given under the auspices of the University College. Lectures have been given on spherical astronomy, to which has been added some practical work with the instruments, and in the present term lectures on meteorology are offered.

Radcliffe Observatory, Oxford.

The work of the staff during the past year has been chiefly directed to the completion of the Radcliffe catalogue of 6424 stars for the epoch 1890, which has now been published and distributed. In the formation of the Catalogue, the observed places have been carefully compared with the results of other Catalogues

for the determination of proper motions; but the determinations have not been generally used in the formation of the Catalogue, or printed, unless they were of sufficient magnitude to be of practical importance, and appeared to be determined with some close approximation to the truth. The observations above and below the pole have been discussed, and a careful comparison made with the places of the Cape Catalogue for 1880 to test the accuracy of the refractions used and the general agreement of both Catalogues. An independent determination of the epoch correction has also been made from a discussion of the Sun observations, and applied to the right ascensions of the Catalogue.

The Radcliffe Catalogue for 1890 and the Cape Catalogue for 1880 afford positions of all the stars in the Southern Hemisphere of not less than the seventh magnitude, except those in clusters, and of fainter stars in those portions of the sky where there are no stars so bright as the seventh magnitude.

The opportunity afforded by the completion of the observations required for the Catalogue was utilised for a general cleaning and overhaul of the transit circle instrument; and a new clamp and slow-motion have been supplied by Mr. Simms.

The observing with the transit circle during the past year has been confined to the observations of the Moon, of a few stars whose place appeared to require further observation, and of comparison stars required for comet observations.

The Barclay equatorial has been employed in miscellaneous observations of *Nova Aurigæ*, *Mars*, and comets.

During the visit of the British Association to Oxford the Observatory was thrown open to members and associates, and a large number availed themselves of the opportunity of visiting the Observatory.

The meteorological work has been regularly carried on, and any information required by engineers and others for practical use has been supplied on demand.

University Observatory, Oxford.

The chief astronomical work accomplished in the year 1894 has been experimental work on the methods of measuring and reducing the plates for the Astrographic Chart. As a preliminary the work initiated by the late Professor Pritchard, of measuring several plates of the *Pleiades* (mentioned in the last report), was completed to a definite stage, and the results have been communicated to the Society (*Monthly Notices*, vol. liv. page 489). The method of rectilinear coordinates was introduced into the reductions and found completely satisfactory, both in accuracy and in great saving of labour. Attention was then directed to the particular problems of the work for the Astrographic Chart. A new micrometer of simple pattern, and with a scale instead of a micrometer screw, was constructed by Messrs. Troughton and

Simms, and received in 1894 October. Meanwhile a microscope and scale was furnished by the same firm for use with a rough wooden apparatus which had served as a model for a similar instrument. Six plates have been completely measured with the rough apparatus or the finished micrometer, and it is found that satisfactory measures can be obtained at the rate of 50 stars an hour, and that these measures may be reduced quickly and simply. It is the settlement of the best processes for attaining this end of simple and rapid reduction which has chiefly occupied the time of the observatory. An exposition of the method finally determined upon is now ready for communication to the Society.*

The number of plates taken for the Astrographic Chart has been few, partly on account of bad weather and partly because the Director, on his appointment in 1893 December, found the astrographic dome so urgently in need of repair that work with the instrument had to be temporarily given up. The repairs on the dome were not completed until 1894 June. Several other instruments have required repair.

Lectures on general astronomy in the Trinity and Michaelmas terms were attended by fifteen to twenty students, two or three of whom have done practical work at the observatory. With a view to teaching the use of a small transit-circle indoors and in the daytime, an apparatus, which may be called an "artificial sky," has been fitted on the roof of the lecture-room. This apparatus, devised by the Director in concert with Mr. Simms, rotates uniformly round a pivot, and carries both equatorial and polar artificial stars; and a small altazimuth (kindly presented to the observatory by Mr. Ernest De la Rue), mounted below on a solid brick pier, can thus be adjusted, not only for collimation and level, but for azimuth, and the clock-error found. The observations hitherto made with this apparatus have been found satisfactory.

The transit of *Mercury* on 1894 November 10 was observed at Sidmouth by the Director.

The scales of the three photometric wedges belonging to the observatory have been redetermined by Captain Abney.

During the visit of the British Association to Oxford, the Observatory was thrown open to members and associates, and a large number availed themselves of the opportunity.

The constitution of the staff remains as in the last report.

Temple Observatory, Rugby.

The educational work of the observatory has been continued as usual, a certain time every fine evening being given up to members of the school. The original work has consisted almost wholly of obtaining measures of double stars, but a few photographs of stellar spectra have been tentatively taken.

* See *Monthly Notices*, vol. lv. p. 102.

Stonyhurst College Observatory.

The meteorological and magnetical work of the observatory has been carried on as usual.

As yet no regular work has been commenced with the Father Perry Memorial Objective. On all the clear nights of the year it has been employed upon a series of experiments in stellar spectro-photography, the leading object being to decide upon the most serviceable form of spectrograph that would suit the equatorial in its new condition under the extra load of the 15-inch objective and its adapting tubes. These experiments, including two months' work with a fine 8-inch disc-prism, kindly lent by Mr. Hilger, will form the subject of a future paper, if the final results prove to be of sufficient interest.

Dr. Common's Observatory, Ealing.

The experiments made with a view of getting a more convenient form of large reflecting telescope mentioned in last year's report have occupied nearly the whole of last year's available working time, and have been brought to a successful conclusion in the form of an Oblique Cassegrain telescope, particulars of which have been laid before the Society.

In the course of these experiments some thirty convex mirrors, from 3 inches to 15 inches diameter, have been made and remade, and one 30 inches concave. The stage for use with the 5-foot has been taken down, and the 5-foot has been temporarily converted into a smaller telescope on the Oblique Cassegrain plan.

Mr. Crossley's Observatory, Bermerside, Halifax.

As in past years the work of this observatory has been chiefly the observations of the phenomena of *Jupiter's* satellites, and of the occultations of stars by the Moon. Meteorological observations are taken twice daily, and reports sent to the Registrar-General, Mr. Symons, and one of the local papers.

Wolsingham Observatory. (Rev. T. E. Espin.)

The total number of objects observed during the year is 1044. Besides the observation with the spectroscope of objects already known, 92 stars of Type III.!!!, III.!! or IV. have been detected, 100 of Type III.!, 276 of III. Sixty stars are under observation for variation. Variations in the following stars have been discovered or confirmed :

Name.	R.A.(1900) h m	Decl. (1900) ° ′	Var.	Type.
D.M. +62°·161	0 45·3	+62 23	8·7 to ?	III.!!?
Es-Birm. 13	0 49·0	+58 1	8·6 „ 10·5	IV.?
Anonymous	1 49·7	+58 46	9·3 „ 10·8	IV.?
D.M. +54°·622	2 49·6	+54 15	8·9 „ 9·6	III.?
D.M. +50°·2251	16 1·5	+50 47	7·8 „ 8·9	IV.?
Anonymous	17 54·9	+58 14	8·0 „ ?	IV.
Anonymous	19 16·9	+37 41	8·3 „ 10·3	IV.!

Dr. Huggins' Observatory, Upper Tulse Hill.

During the earlier part of the year much time was occupied in the completion and the final adjustments of the new spectroscopic apparatus.

Work on the spectrum of the *Orion* and other nebulæ by photography was commenced in the autumn, and as much progress as was possible, considering the unfavourable weather, has been made in obtaining photographic spectra of the nebula, and of the stars apparently involved in it.

The question as to the reality of the atmospheric bands observed by Dr. Huggins in the spectrum of *Mars* during the years 1862–67 having been raised by observations made on the planet at the Lick Observatory, the photographic work was interrupted for a short time in November for the purpose of repeating those early comparisons of the spectrum of *Mars* with that of the Moon at similar altitudes, with the more modern spectroscopes now attached respectively to the refractor and to the reflector, mounted on the Tulse Hill equatorial. Visual observations were made with the former, and photographs of the spectrum of the Moon and of *Mars* were taken with the reflector, which extend as far as S in the ultra violet.

The results confirm Dr. Huggins' early observations that under similar conditions of altitude, and even when the Moon is lower than *Mars*, some atmospheric bands near D were distinctly stronger in *Mars*; while in the part of the spectrum more refrangible than F, no indications of atmospheric absorption, as had already been shown by Dr. Huggins in 1879, could be detected in the photographs. In addition to the indications of planetary absorption, at, and on the red side of D, a dark band was observed on some nights on the blue side of D, beginning at the stronger end at about λ 5860, and traceable to beyond λ 5840. It is suspected that this band may belong to the atmosphere of *Mars*, and may be variable, possibly in accordance with conditions prevailing on the planet.

Rousdon Observatory, Lyme Regis. (Mr. Peek.)

The establishment continues in good working order, and observations have been made on 160 nights, this being about the average number.

The 6·4-inch Merz achromatic telescope has been regularly employed on long period variable stars, and 511 determinations of magnitude have been secured. Special attention has been given to S *Coronæ*, S *Herculis*, and R *Cygni*. Each of these stars when passing the minimum phase has exhibited the phenomenon of a very minute stellar point, disappearing, and leaving its position occupied by a very faint bluish nebulous haze. Since the work commenced in 1885 December, thirty long-period variables have been observed, and 141 maxima and 121 minima have been determined.

All variables on the working list are observed at least twice monthly throughout the whole of their periods, and not merely at maximum and minimum.

Transit observations have been taken as often as required.

Gale's Comet was observed on twelve nights between May 4 and July 14; for the first week it was distinctly visible to the naked eye. Encke's Comet was viewed on November 25, when it was excessively faint: it has since become easily visible in small telescopes.

The ingress of *Mercury* at the transit on November 10 was observed under most favourable conditions, and the times of external and internal contact at ingress noted. There was no trace of any white spot, nor of any ring or halo round the planet, and during the twenty-five minutes it could be observed it appeared as a very black, circular, well-defined disc.

Dr. Isaac Roberts' Observatory, Crowborough Hill, Sussex.

The photographic work at this observatory has been maintained during 1894 on the same plan as in preceding years, but the number of really first-class nights has been somewhat below the average.

The following list of photographs of nebulæ and clusters shows the longer exposures taken, and is in continuation of that published in the *Monthly Notices*, vol. liv. pp. 229, 230.

	R.A. h m	Decl. ° ′	Expos. m
Great Nebula in Andromeda	0 36	+40 30	90 (2 photos)
Neb. H I. 112 Arietis	1 53	+18 30	90
Neb. H I. 101 Ceti	1 54	− 6 29	38, 90
Neb. H I. 154 Persei	2 24	+36 40	90
Neb. H I. 63 Eridani	2 36	− 8 41	39
Nebulæ in Pleiades	3 40	+23 46	720

(On 1893 Dec. 30, 1894 Jan. 2, 6, and 7)

	R.A. h m	Decl. ° ′	Expos. m
Neb ♅ I. 217 Aurigæ	4 23	+35 3	180
Great Nebula in Orion	5 30	− 5 27	60 (2 photos)
„ „ (on Feb. 3 and 8)			455
Neb. M. 78 Orionis	5 41	+ 0 1	44 and 3[h]
Cl. M. 46 and Neb. ♅ IV. 39 Argûs	7 37	−14 30	90
Cl. ♅ VI. 37 Argûs	7 55	−10 20	90
Neb. M. 65, 66 and ♅ V. 8 Leonis	11 14	+13 50	220
Neb. ♅ I. 19 Comæ Berenicis	12 4	+19 8	110
Neb. M. 98 Virginis	12 8	+15 29	240
Neb. ♅ I. 75, 89, 90 Comæ Ber.	12 14	+29 30	90
Neb. ♅ I. 77 Comæ Berenicis	12 21	+31 48	65
Neb. ♅ I. 31 Virginis	12 28	+ 8 17	90
Neb. ♅ I. 83 and V. 24 Comæ B.	12 28	+26 28	90
Neb. ♅ V. 2 Virginis	12 29	+ 2 46	90 and 180[m]
Neb. ♅ V. 24 Comæ Ber.	12 31	+26 34	180
Neb. ♅ I. 92 Comæ Ber.	12 31	+28 43	105 and 120[m]
Neb. ♅ I. 178, 179 Canum V.	12 36	+41 44	90
Neb. ♅ V. 42 & I. 176, 177 Comæ B.	12 38	+32 55	90 and 3[h]
Neb. ♅ I. 39 Virginis	12 43	− 5 14	90
Neb. ♅ I. 129 Virginis	12 43	− 8 8	65
Neb. ♅ I. 84 Comæ Berenicis	12 45	+26 5	90
Neb. ♅ I. 143 Virginis	12 55	+ 3 4	90 and 3[h]
Neb. ♅ I. 130 Virginis	13 0	− 7 27	90
Neb. ♅ I. 190, 191 Boötis	13 54	+37 57	54
Neb. ♅ I. 99 Boötis	14 14	+37 0	90
Neb. ♅ I. 144, 146 Virginis	14 15	+ 4 6	90
Neb. ♅ I. 182 Virginis	14 34	+ 0 10	90
Neb. ♅ I. 126 Virginis	14 39	+ 2 24	54
Neb. ♅ I. 127, 128 Libræ	14 58	+ 2 4	77
Neb. ♅ II. 751, 752 Boötis	15 2	+20 0	56
Neb. ♅ I. 148 Serpentis	15 16	+ 5 27	90
Cl. M. 16 Clypei	18 13	−13 50	60
Cl. Ä 2017 Aquilæ	18 36	− 4 52	60
Cl. Ä 2018 Aquilæ	18 36	− 6 20	60
Stars in Cygnus	19 45	+35 30	60 (2 photos)
Cl. ♅ VIII. 20 Cygni	20 7	+26 11	50
Cl. ♅ VI. 42 & Neb. ♅ IV. 76 Cephei	20 31	+60 3	60
Cl. ♅ VII. 53 Lacertæ	22 1	+45 57	60
Cls. Ä 2159, 2161 Cephei	22 19	+57 26	60

Beside the foregoing a number of shorter exposures have been taken, including such objects as Denning's Comet (exp. 45^m), March 29; Gale's Comet (exp. 15^m), May 7; Encke's Comet (exp. 30^m), December 18; occultation of *Spica*, March 22, &c. Enlarged copies of some nebulæ and clusters named in the list have been presented to the Society, and lantern slides of the same exhibited at the meetings.

The work entitled "A Selection of Photographs of Stars, Star-clusters, and Nebulæ," which was alluded to in the preceding report as being in preparation, has been published by Messrs. Witherby & Co., and is now available to those interested in the study of celestial photography.

Some considerable portion of the autumn months was occupied in testing the new triple objective of 6-inch aperture, made by Messrs. T. Cooke & Sons. The lens proved to be *perfectly* "achromatic," no trace of secondary colour being visible around even the brightest objects. The visual and photographic foci were found, from a great number of careful experiments, to be exactly coincident, as in a reflector.

Mr. Wilson's Observatory, Streete, Westmeath.

During the past year the 24-inch reflector was principally used for photographic purposes, and some very satisfactory negatives of clusters and nebulæ were taken. The large heliostat was used in the experiments on the radiation from sun-spots, and the results will shortly be published. The weather has been very cloudy, and the number of good nights very few and far between. A 4-inch photographic telescope was ordered from Sir H. Grubb for taking solar photographs, but it arrived too late in the year to do any work with it.

Hongkong Observatory.

The time service and transit observations of the Moon and planets have been continued as usual. Absolute magnetic observations have been made regularly. Hourly meteorological observations have been continued without interruption. The main object of this observatory is marine meteorology, investigations of typhoons, and storm-warnings. During the absence of the Director in summer and autumn Mr. Plummer took charge of the astronomical observations, Mr. Figg took charge of meteorological work and storm-warnings, and Miss Doberck attended to marine meteorology. During his leave of absence the Director was engaged in a redetermination of the orbit of the first comet, of 1824, observed by Sir T. M. Brisbane in Queensland. The Lee equatorial was remounted on granite piers last spring, but unfortunately the dome

was blown away during a typhoon in the autumn, as it had not been sufficiently secured by the iron bolts which were supplied for the purpose.

Madras Observatory.

During 1894 the work of reducing and printing the old observations was carried on as rapidly as possible, and vol. viii. of the *Meridian Circle Observations* was received from the press at the close of the year. This completes the series of preliminary volumes, and leaves (for this part of the work) only the General Catalogue, with which considerable progress has been made.

The investigation of the circle errors has been taken in hand, and the reduction of all the observations of circumpolar stars for the determination of the latitude correction is far advanced.

The time service and meteorological records were maintained as in former years. Observations were made of the two solar eclipses, of Z *Herculis*, and of several comets.

Much of the time of the Government astronomer has been taken up with questions connected with the new observatory at Kodaikanal, and matters have advanced so far that building operations will probably be begun within the next three months.

Melbourne Observatory.

During the past year the work at this observatory has been somewhat curtailed owing to the necessity for continued retrenchment in the public service of the colony. The routine work in connection with time distribution, meteorology, terrestrial magnetism, has, however, been regularly continued as heretofore, but many minor changes for the lessening of clerical work have been adopted. Meridian observations have also been carried on as usual, and the work done up to the end of November comprises the observation of 2379 stars in R.A., and 1226 in N.P.D., including the determination of the positions of 446 stars selected from the astrographic catalogue plates for use in the final measurements.

The astrographic work on the Melbourne zones (65° to 90° S.) has been steadily proceeded with; the weather, however, has been remarkably unfavourable for the undertaking, and as no photographs are obtained except on really good nights, the number of plates secured during the year was only 368, comprising 290 catalogue, 17 chart, and 61 type plates. One of the *réseaux* ruled on plates coated with asphalt varnish, referred to in last year's "Proceedings of Observatories," has been in continual use throughout the year, and has been found very satisfactory. Those ruled on plates coated lightly with Blundell and Spence's

Brunswick Black stand the test, and show no signs of "flaking" or "pinholes" after a year's work.

Some further pendulum observations were made in July, August, and September. A set of half-seconds pendulums, somewhat like those of Colonel von Sterneck, having been constructed, determinations of their constants were undertaken, as well as a series of observations for the value of g by means of them by Mr. P. Baracchi, chief assistant, and Mr. E. F. J. Love, M.A., Lecturer in Physics at the Melbourne University. In September Mr. Love took these pendulums to England, intending to swing them at Kew or Greenwich, and probably at the Cape also, on his return voyage to Melbourne. It is hoped that these observations will furnish information as to the value of small pendulums for determining differences of g at different parts of Australia, and also a further trustworthy determination of the difference of g between Kew, the Cape, and Melbourne.

Scarcely any extra-meridian work has been done, and beyond a few comet places, and an occasional astronomical occurrence, there is nothing to record.

The great telescope was laid up during the winter months for repair and cleaning; the mirrors now in use are in good condition and perform satisfactorily. A new secondary mirror of silvered glass was made during the winter, and the metal ones repolished. At the request of Mr. Pickering, *Mars* was carefully watched in May and June with this telescope, and the changes of the south polar cap observed during these months. It is intended to try this telescope for some photographs during the summer months, but it can only be used for moderately short exposures, as it is impossible to drive it steadily for any length of time unless in a dead calm.

Sydney Observatory.

No change in the staff has been made since the 1893 report. Additional workers are urgently needed, but in the present depressed times there is no hope of increasing the staff.

Transit Circle.—The weather during 1894 for the months January to October inclusive has been rather better than usual, but for November and December it has been very bad. Counting as fine nights those wholly fine and those fine for an hour or two, we have had 145 nights on which observations and photographs could be made.

During the year 1481 transits have been observed by Mr. Lenehan, of these 457 were of the Sun's limb for public time, and 283 clock stars; 741 transits of the reference stars of our zone were observed, and 713 in N.P.D.

The error of Azimuth was determined 91 times; Collimation, 298; Level, 381; Nadir, 375.

The stars observed in 1892 are ready for the press. The computations of those for 1893 are almost completed, and those for 1894

in a forward state. The observation of guide stars for the centres of the photographic plates is well forward, and another catalogue, giving a reference star in each quadrant of each plate, is in course of preparation and observation. No longitude or other work outside the stars for our zone has been done with the transit circle. Through the courtesy of Dr. Hay, the new proprietor of the property on which our N. meridian mark stands, the trees which have for some years covered the mark have been removed, and it is now quite clear and useful for some purposes: it is distant $1\frac{3}{4}$ mile and 340 feet above the sea.

Equatorial.—Ninety-five nights (exclusive of Sundays) have been fine enough for work with this instrument. Of these nights forty-eight were devoted to measuring double stars, fourteen to comet observations, twenty to visitors; on eleven the definition was so bad no measures could be taken, and on two Mr. Sellars was at work with the transit circle.

No new double stars have been added to the list. Fifty-three pairs of stars have been measured 100 times, involving 400 sittings for position angles, and 380 for determination of distance. All the measures are reduced and ready for publication.

Comet Gale was compared with sixteen catalogue stars ninety-nine times.

The double-star results of 1892 and 1893 have been published in *Ast. Nachr.* No. 3240. Some of the comet observations were published in *Ast. Nachr.* No. 3255, and the complete set in *Monthly Notices*, vol. liv. No. 8.

Mars in opposition was regularly observed, but nothing worthy of special note was seen.

Photographic Work.—There were fine or partially fine 145 nights, not quite so many as in 1893, but a much larger number of plates were taken, the difference being due to two causes: First, there were more nights fine right through; and second, and chiefly, because the plates used would record a good image of an 11 magnitude star in one minute. The total number of catalogue plates obtained was 876, thus leaving only 70 plates to complete the Sydney zone. These would have been easily taken in November and December with ordinary weather.

Guide stars have been selected and observed for four positions in which the catalogues contained no stars. We hope to complete our catalogue plates this month. No chart plates have been taken. Nine plates were taken of Comet Gale, 53 for parallax, 79 to investigate certain nebulæ and clusters of stars, and 53 test plates, making in all 1070.

In 1891 the best plates we could obtain required an exposure of eight minutes to record an eleventh magnitude star by our present plate maker (Marion). This time has been gradually reduced to one minute on the plates we are now using. A great deal of time has been given to experiments in star measuring, and the form of micrometer proposed by Professor H. H. Turner has been adopted.

Meteorology.—The general meteorological service has been actively maintained, and the number of observers increased to 1278. The volume of rain and river results for 1893 has been printed and published.

The weather chart service, with two issues daily and two forecasts, has been actively maintained and improved.

General.—There have been received from other observatories and publishers, in exchange for our publications, 940 volumes and pamphlets; our publications to the number of 3500 have been sent out.

Visitors to the observatory continue to increase, and are becoming a very serious charge upon our time. 217 persons have called to consult upon scientific matters, 830 persons have called to see the observatory, and 97 have applied by letter for information, which has involved twenty-eight days' work to supply. This is a serious but unavoidable demand upon our time.

In January Mr. Love, Demonstrator in Physics in Melbourne University, acting for the Gravity Committee of the Royal Society of Victoria, brought here, in pursuance of the work undertaken, the original Kater invariable pendulums, and they were swung in exactly the same place they occupied in 1882 January. In May an Austrian man-of-war arrived with another set of half-seconds pendulums for gravity observations, and these also were swung in the same part of the observatory cellar.

A number of experiments have been made to determine the amplitude of vibration of stars in times of bad definition, one small star with an estimated diameter of 1½ inch vibrated 4½ seconds, that is from wire to wire set 7½ inches apart.

The transit of *Mercury* (egress) was observed, and result published.

The 10-foot standard bar of Queensland has been very carefully compared with the two 10-foot standard bars of New South Wales; all three steel tapes used in the Queensland trigonometrical survey have been compared with our standard 10-foot bars.

On October 26 Messrs. Ellery, Todd, and Russell met in conference in Melbourne in furtherance of their astronomical and meteorological work.

A chart of southern circumpolar stars, designed for the convenience of surveyors and amateur astronomers, has been prepared in the observatory. It is accurately made, and much clearer than existing south circumpolar charts. It is 30 inches in diameter, and includes all stars to 6½ magnitude.

In 1893 December Parliament passed an Act providing that "the mean time of the one hundredth and fiftieth meridian of longitude east of Greenwich in England shall be deemed and is hereby declared to be standard time throughout New South Wales." This comes into operation on 1895 February 1.

Mr. Tebbutt's Observatory, the Peninsula, Windsor, New South Wales.

It will be seen from the following summary that the results accomplished at this observatory during the year 1894, though of considerable importance, are not so abundant as usual. The rule hitherto has been to determine the local sidereal time as often as the weather or the observer's avocations permitted, but the determination of time during the past year has been confined almost wholly to those nights on which extra-meridian observations were made. Transits were accordingly observed on seventy-nine nights, the number, exclusive of stars in high south declination for azimuth, being 450. The separate determinations for level, collimation and azimuth were 203, 33, and 81 respectively. It was three times found necessary to adjust for level error, but no adjustment was made for either collimation or azimuth. The rate of the sidereal chronometer has been found satisfactory.

With the 8- and 4½-inch equatorials, twenty-six disappearances of stars were observed at the Moon's dark, and six at the bright limb, and eight reappearances at the dark and the same number at the bright limb : altogether forty-eight phases. Ten *Nautical Almanac* stars were observed in both phases, including an occultation of *Antares* on October 31. The disappearance in this case occurred in full sunlight, and the reappearance in strong twilight. The observations of the daylight occultations of *Spica* and *Antares*, on November 24 and December 24 respectively, were unsuccessful in consequence of dense smoke from bush fires in the former case, and cloud in the latter. An excellent observation of the disappearance of *Venus* at the bright limb was made on May 1. Messrs. Innes and Brooks, Fs.R.A.S., have kindly supplied the observatory with prediction calculations of occultation phenomena.

On the morning of April 3, civil time, a notification was received from Mr. Walter F. Gale, of Paddington, of his discovery of a comet (Comet II. 1894), and observations were obtained here on the evening of the same day. The resulting place, with the discoverer's name and the date of discovery, was telegraphed the next day to the Melbourne Observatory. The weather was remarkably favourable for the observation of the comet, and excellent positions were obtained here on twenty-seven evenings, from April 3 to May 11. A determination of the orbit was also published, based on the extreme and middle observations of the series, and it was found to agree very closely with that derived by Herr Kohlschütter, of Kiel, from the Windsor observation of April 6, and Cape and European positions extending to May 9. At the request of Dr. Schulhof, an attempt was made to follow the periodical comet of Tempel 1873

II., at its recent return to perihelion, but in consequence of the extreme faintness of this object only one observation of any value could be secured. Encke's comet was picked up with the 4½-inch equatorial on December 20, but it was low, and the weather turned out very unfavourable. It will probably be better observed in the morning sky in February next.

The following interesting southern double stars were measured with the 8-inch equatorial during the last three months of the year: *β* and *ζ Phœnicis*, *κ Toucani*, *h* 3447, *p Eridani*, *h* 3592, *Lacaille* 2145, *α Centauri*, *γ Coronæ Australis*, *Lacaille* 8550, *h* 5295⅔.

The usual meteorological observations have also been regularly made, the past year being the thirty-second since the establishment of this department of observation. All the astronomical, and about ninety per cent. of the meteorological observations, and by far the greater portion of the reductions, both astronomical and meteorological, have been made by the proprietor himself.

Notes on some Points Connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1894.

Twenty-three new planets were discovered during the past year, as follows :—

Provisional Designation.	Permanent Number.	Date of Discovery, 1894.	Discoverer.	Place of Discovery.
AQ	379	Jan. 8	Charlois	Nice
AR	380	8	,,	,,
AS	381	10	,,	,,
AT	382	29	,,	,,
AU	383	29	,,	,,
AV	384	Feb. 11	Courty	Bordeaux
AW	...	Jan. 30	Wilson	Northfield, Minn.
AX	385	Mar. 1	Wolf	Heidelberg
AY	386	1	,,	,,
AZ	387	5	Courty	Bordeaux
BA	388	7	Charlois	Nice
BB	389	8	,,	,,
BC	390	24	Bigourdan	Paris
BD		Nov. 1	Wolf	Heidelberg
BE		1	,,	,,
BF		7	,,	,,
BG		7	,,	,,
BH		19	Borelly	Marseilles
BK		30	Charlois	Nice
BL		Dec. 1	,,	,,
BM		19	,,	,,
BN		28	,,	,,
BO		Apr. 9	Roberts	Crowborough

The letter BI was assigned to a planet discovered by Charlois on November 24, which was subsequently found to be identical with No. 369. AW and BO were discovered on photographs

taken for other purposes than the discovery of planets, the first being on a photograph of the *Pleiades* and the second on a photograph of the nebula H I 143.

Only one planet has received a name since the date of the last report, viz. No. 321, which has been named *Florentina*. An error in the last Report may be noticed here: the name of No. 316 should be *Goberta*, not *Roberta*, the latter being the name of No. 335, as given in the Report for the previous year.

The number 359 has been assigned to 1893 M, discovered by Charlois 1893 March 10.

The planet BE has an interesting orbit, its perihelion distance (1·60) being the smallest of the entire family, with the possible exception of 323 *Brucia*. Its least distances from the orbits of the Earth and *Mars* are about 63 and 21 millions of miles respectively. This planet is therefore well adapted for determining the Solar Parallax.

The planet No. 387 will be of about the 7th magnitude in favourable oppositions. No. 388 must have been close to 1892 S when the latter was discovered in 1892 December. The two planets, however, are not identical.

None of the nine missing planets enumerated in the last Report have been picked up. In addition to these, the following fourteen planets discovered in 1890 and 1891 have not been seen at any subsequent opposition:—Nos. 290, 293, 296, 307, 309, 310, 314, 315, 316, 318, 319, 320, 322, 323.

Professor Barnard has measured during the past year the diameters of *Ceres*, *Pallas*, and *Vesta* with the 36-inch equatorial at Mount Hamilton. His results have been already given in the *Monthly Notices* (vol. liv. No. 9). The diameters come out:—*Ceres* 520 miles, *Pallas* 304 miles, *Vesta* 241 miles. The great excess in size of *Ceres* over *Vesta* is surprising, and the latter planet must have a high albedo to account for its relative brilliancy. A. C. D. C.

Comets of 1894.

The following comets have been discovered in 1894, and on some grounds are more than usually interesting.

Comet *a* 1894, by Denning.
Comet *b* 1894, by Gale.
Tempel$_2$ 1873, by Finlay.
Encke, by Perrotin, Wolf, Cerulli.
Comet *e* 1894, by E. Swift.

The first of these, discovered on March 26 in the constellation *Leo Minor*, was a faint object, and unfortunately growing fainter. The perihelion passage occurred about February 9, and the comet was increasing its distance from both Sun and Earth, so that notwithstanding a favourable position in the sky for ob-

servation, it has been somewhat inadequately observed. This is the more to be regretted, since the orbit is very interesting. Its ellipticity was early noted, though the period remained somewhat doubtful, and definitive elements are still wanting. From his first elements, M. Schulhof, pointed out that the orbit made a close approach, less than one-fifth of the Earth's distance from the Sun, to the orbit of *Jupiter*, in Hel. Long. 287°, and that in 1889 the two bodies had made a close approach. Further, that Tisserand's well-known criterion was satisfied in the case of two imperfectly observed comets—viz., 1743, I., and 1819, IV.—and the present comet. Later, M. Schulhof called attention to the fact that the point of closest approach between the orbits of *Jupiter* and the comet coincided very approximately with that of *Jupiter* and Brorsen's comet, and this fact has been further emphasised by Dr. Hind, who shows that the two comets, Denning and Brorsen, were actually near each other in 1881 April. Dr. Lamp, to whom we are indebted for the most accurate investigation of Brorsen's comet, shows that the two orbits intersect in Long. 284° 47′ and South Latitude 1°·57′, and that this point was passed by Brorsen on 1881, February 7, and by Denning 1881, March 14. This latter date depends on Schulhof's elements, which are still somewhat doubtful, and to secure the closest possible approach it would be necessary to diminish the mean daily motion found by Schulhof some 28″. This alteration seems large, implying as it does an error in the period of nearly half a year, but between the orbits of Schulhof and Hind there exists a still greater difference. M. Schulhof has employed an observation on May 22, while Dr. Hind's orbit rests on positions prior to May 6; this fact shows the importance of observations being continued as long as possible, but the Nice observation on June 5 appears to be the last.

For the second comet we are indebted to the energy of Mr. Gale, an amateur astronomer of New South Wales, and the discovery is an encouragement to all who work with small instruments, for Mr. Gale writes that he detected it with a 3-inch telescope. The comet was observed for a month at Windsor, N.S.W., Melbourne, &c., before it became visible in Europe, when, having reached its greatest brilliancy, it was a fairly conspicuous object in our western skies. A photograph taken at Paris on May 5, showed a tail 4° long, but the most complete study of its general features was made by Mr. Barnard at the Lick Observatory. A full account, with an admirable reproduction of one of the plates, appears in *Astronomy and Astro-Physics* for 1894 June. In the spectrum, which resembled that of the bright comet of 1893 (Rordame-Quénisset) more than twenty lines could be traced. The orbit shows no deviation from the parabola.

Tempel$_2$ 1873 comet, at its recent return was very unfortunately situated for observers in the Northern Hemisphere, rising about two hours before the Sun. More fortunately situated in the Southern Hemisphere, Mr. Finlay, of the Cape of

Good Hope Observatory, succeeded in finding it on May 8 by the aid of the ephemeris provided by M. Schulhof. The error in the assigned position was only nine seconds of right ascension and thirty seconds in declination, implying an increase of the mean anomaly of only 51″, a result upon which M. Schulhof may be congratulated, more especially when we remember that the comet has not been observed since 1878. The number of observations made at the Cape, at Windsor, N.S.W., and elsewhere is very few, owing to bad weather and the faintness of the comet, but the recovery of the comet after sixteen years is most satisfactory.

Encke's comet at its recent return was independently discovered by, at least, three observers. M. Perrotin at Nice obtained an observation on October 31 with the great equatorial, and described the comet as at the extreme limit of visibility in that telescope. On the same evening M. Wolf, at Heidelberg, secured a photographic record of the presence of the comet, but could not make any accurate determination of place. Dr. Cerulli, in Teramo, also saw the comet on November 1 as a faint nebulous object, but did not record the place with accuracy. These astronomers were assisted by the excellent ephemeris of Dr. Backlund, whose elaborate calculations on the motion of this comet have been highly appreciated, and whose intended withdrawal after his long supervision has been heard with so much regret. Not less valuable than the preparation of the ephemerides at each return of the comet is his determination of the mass of *Mercury* from the perturbations of this comet. In 1891, an approach to that planet was made, and the result of the discussion of the long series of observations has been to give a value, the most trustworthy, if the smallest, which has yet been assigned. This comet is still under observations and will be followed for some time longer in the southern hemisphere.

The last comet to be discovered was a very faint object, first seen on November 21 by Mr. E. Swift, of the Lowe Observatory, California (whither the Rochester Observatory has been removed). The comet was very faint, and like Denning's, had passed its perihelion, and was growing fainter. It had a considerable southern declination, but with northern motion; this advantage was, however, diminished by the growing faintness of the comet. Almost concurrently with the announcement of the discovery Dr. Berberich suggested the identity of the comet with the lost *De Vico*, and further examination and calculation support the suggestion. The arguments in favour of the identity are: the increase in the longitude of the perihelion and the decrease of that of the node, results which must follow the perturbation of a comet of short period with direct motion; the satisfaction of the Tisserand criterion; and the fact that both comets, supposing them to be distinct, were, according to the elements of Brünnow and Schulhof, respectively, in the neighbourhood of *Jupiter* in 1885, and that an increase in the period, such as that indicated, is likely

to result from the perturbations. It is to be hoped that the observations will be sufficiently numerous to permit a rigorous determination of the orbit, and the decision of this interesting question. So many comets have exhibited unexpected increase of brilliancy, notably that of Holmes, that it occasions less surprise that a comet should remain invisible for fifty years and once again become a recognisable member of the system.

In addition to these it may be mentioned that an object photographed during the solar eclipse of 1893 April 16, has in the last year been generally recognised as a comet. This fact recalls the observation made under similar circumstances in May, 1882, at Sohag, and suggests that many comets pass through their perihelia without being detected.

W. E. P.

Progress of Meteoric Astronomy in 1894.

January Meteors.—At the epoch of the return of the *Quadrantids*, early in 1894 January, a very intense frost provailed over England, and not many shooting stars were observed. A few were, however, recorded by Professor Herschel, at Slough, Mr. Corder, at Bridgwater, and Mr. Denning at Bristol. On January 2, at about 7^h, Mr. Corder found the *Quadrantids* very active for a short time, the rate of apparition being about 40 or 50 per hour. He determined the radiant as at $219°+53°$ from 14 meteors, and found a neighbouring radiant in *Hercules* at $240°+48°$. A meteor of about second magnitude from the latter position was mapped both at Slough and Bridgwater on January 2 at $9^h\ 40^m$. It fell from a height of 65 miles above Cirencester, Glos., to 56 miles above Cranborne, Dorset, and traversed a real path of 53 miles with a velocity of about 21 miles per second.

April Meteors.—The moon was full on the 20th, and prevented successful observation. Mr. Corder watched for an hour on the 22nd with no result, and on the 23rd saw only 4 meteors in two hours. The only conspicuous *Lyrid* recorded at Bristol appeared on April 22, $9^h\ 59^m$, shooting from $260°+59°$ to $243°+72°$, and leaving a bright streak.

May Meteors.—On the mornings of May 1, 2, 4, 6, 7, and 10 Professor Herschel made a series of observations with a view to redetecting the fine shower of *Aquarids* discovered by Lieut.-Colonel Tupman in 1869. About 11 meteors of this system were mapped, but indicated a radiant not very sharply defined. Contemporary showers manifested themselves from the points $309°-17°$, $245°-20°$, $227°+47°$, and $25°+25°$.

August Meteors.—In the *Comptes Rendus*, 1894, No. 12, Padre F. Denza gave a summary of observations of shooting stars at 24 stations in Italy on the nights of August 9, 10, 11, and 12, the total number seen on the four dates being 1805, 5226, 2468,.

2336 respectively, making an aggregate of 11835. At one of the stations, Montevergine, 4500 feet high, a fine display of *Perseids* was witnessed on the morning of August 11 at about 3 A.M., when shooting stars fell so plentifully that the exact number could not be counted. The chief position for the *Perseid* radiant, as determined at the Vatican Observatory, was at 45°+54°, and minor showers revealed themselves in *Cassiopeia*, *Draco*, and *Cygnus*.

At Utrecht Messrs. Nyland and Bolt noted 23 meteors within the 50 minutes from $12^h\ 22^m$ to $13^h\ 12^m$ on August 10. Of these 17 were *Perseids* with an apparently duple radiant at 38°+57° and 43°+54°·5. On August 13, from $13^h\ 30^m$ to $15^h\ 0^m$, the same observers counted 29 meteors, including 15 *Perseids*. A radiant in *Cassiopeia* at 22°+53° was also indicated from 5 meteors.

In England the weather of August was very unfavourable generally for meteoric observation. At Bridgwater the clouded skies prevented Mr. Corder from noting more than 8 *Perseids*. In July, however, he had redetected the *Aquarids* (usually forming a very pronounced display at the close of that month) and from 15 tracks found two radiants at 335°−14° and 338°−3°. The prevailing atmospheric conditions during the *Perseid* epoch appear to have been more auspicious in the north than in the south of England, for Mr. E. R. Blakeley, at Dewsbury, obtained successful views of the shower on August 6, 9, and 10, and derived the radiant as follows :—On August 6 there were apparently two centres, 39°+51° and 40°+56° (14 meteors). On August 9, one centre, 42°+56° (15 meteors). On August 10 from $10^h\ 40^m$ to $12^h\ 10^m$ the directions conformed with a radiant at 45°+55° (24 meteors), while on the same night from $12^h\ 40^m$ to $14^h\ 0^m$ the radiation seemed different, and showed a major shower at 42°+54° (20 meteors), and a minor one at 40°+59° (8 meteors). Mr. Blakeley describes his radiants as pretty definitely marked. Mr. D. Booth, at Leeds, also noticed an apparent displacement of the radiant at different hours of the same night.

On August 10, $11^h\ 35^m$, a fine *Perseid*, nearly as bright as *Jupiter*, was recorded by Mr. T. W. Backhouse at Sunderland, and by Mr. Blakeley at Dewsbury. The pair of observations are in excellent agreement, and prove the meteor to have been unusually low in the atmosphere. When first seen it was 52 miles high over a point in the North Sea in lat. 54° 16′ N., long. 0° 55′ E., and disappeared at an elevation of 16 miles in lat. 53° 55′ N., long. 0° 10′ E.

On October 2, between 10^h and 11^h, Mr. Corder noted a good flight of meteors from near *α Piscium*. In October and November the same observer recorded many slow meteors from a point in *Lacerta* at 323°+53°. The *Taurids* were not very numerously in evidence, though twenty-five of them were seen, and there appeared to be three radiants at 55°+27°, 57°+22°, and 67°+15°.

He also registered during the last week in October, and during November, 9 *Arietids* from 47°+19°, and 12 *Cetids* from 50°+6°. The October *Orionids* and November *Leonids* escaped suitable observation in consequence of brilliant moonlight. Between November 14 and 18 Professor Herschel watched the heavens during periods amounting in the aggregate to three or four hours, but not a single shooting star could be discerned in the partially clouded and moonlit sky. Mr. Corder, however, obtained glimpses of 4 *Leonids*, and of one or two *Andromedes*, but the weather was cloudy after November 25. The full Moon on December 12 interfered with the visibility of the *Geminids*, and no regular watches were undertaken at that period. The shower, however, appears to have returned pretty conspicuously on the morning of December 13, for an observer at Montreux (Suisse) says that at about 7.30 A.M. a considerable number of shooting stars were observed in the N.E. sky, not less than twenty being counted in about 10 minutes, after which the growing daylight prevented further observation.

Fireballs.—January 25, $10^h\ 1^m$. Detonating. Fell from 89 to 16 miles, over the Irish Sea to Tewkesbury. Real length of observed path 160 miles in 9 seconds (mean of 12 estimates). At Droitwich, Worcester, and other places in the Midlands the fireball caused a vibration like an earthquake shock, and people ran out of their houses in alarm. Radiant 331°+55°, near ϵ *Cephei* (see *Monthly Notices*, March 1894, p. 337).

February 8, $0^h\ 28^m$. Splendid meteor, observed in the sunshine of mid-day. Dr. A. A. Rambaut, of the Dunsink Observatory, witnessed the descent of the meteor, and collected a number of other observations, from which he found that, at first appearance, its height was 87 miles over the Irish Sea, and that at disappearance it had fallen to an elevation of 15 or 20 miles over a point near Leeds. Mr. W. H. Wood, of Birmingham, has also computed the real path of this body, and gives it as 80 miles above the Irish Sea to 17 miles above York; a result in substantial agreement with that deduced by Dr. Rambaut. The fireball moved swiftly from a radiant in *Hercules*.

February 21, $7^h\ 18^m$. Brilliant flashing meteor seen at Bristol, Dundee, North Lincoln, &c. The observations are not sufficiently full and exact to enable a reliable path to be computed. At its disappearance, however, the meteor seems to have been 30 miles high over a point near Bolton, Lancashire. It belonged to a radiant probably near θ *Ursæ Majoris*.

April 22, $7^h\ 36^m$. Large fireball observed in the evening twilight. It descended from 80 to 17 miles above Hastings to Amiens, France. Course, 120 miles in 4 seconds; velocity, 30 miles per second. Radiant not certainly defined by the observations, but somewhere in the region of α *Persei*.

August 26, $10^h\ 20^m$. Very fine meteor, moving swiftly, and giving a flash like vivid lightning, observed at many stations in the southern part of England. When first seen it was 90 miles

above a point in the river Mersey, and, travelling rapidly southwards, it ended its visible career at 30 miles above Ruthin, Denbighshire. Its observed course extended over 66 miles, and it left a very luminous streak, which was 9 miles long at first. This streak may justly be said to have formed the most remarkable meteoric apparition of the year. Its long duration, rapid drift in the higher region of the atmosphere, and successive transformations were among the more noteworthy features it presented. At many places it appeared, at first, as a phosphorescent bar, 2° or 3° long, and lying nearly vertical amongst the stars of *Ursa Major*. Quickly becoming convoluted, it drifted to S.E., and finally condensed into an irregularly shaped mass of nebulosity. At the moment of its first projection the middle of the streak was 54 miles high over a point 7 miles N.E. of Denbigh, and when last seen, 30 minutes after, by Mr. Corder at Bridgwater, it maintained the same elevation, but was then placed over a point 6 miles W. of Wolverhampton. This horizontal movement had therefore extended to 61 miles, so that the rate per hour was 122 miles, or 176 feet per second. At 10.37 it was seen by Mr. Packer, at King's Heath, near Birmingham, clouding the star ι *Draconis*, and at that time it formed a roundish mass 2° in diameter, which is equivalent to a real diameter of nearly four miles. The meteor belonged to a radiant at 305°+79° near κ *Cephei*, and there appears to be a well-defined shower of bright, swift meteors, often leaving streaks, from this point both in August and September.

Many other fireballs were recorded during the year, notably on May 18, August 20, September 8, 24, 26, 29, &c., but the observations were not sufficiently numerous and exact to allow the real paths to be computed satisfactorily. W. F. D.

Total Solar Eclipses.

As only a few of the reports on the total solar eclipse of 1893 April 16 have yet been published, references to the results obtained are deferred until next year.

A Permanent Eclipse Committee of Fellows of the Royal and Royal Astronomical Societies has been formed for the consideration of the observation of future eclipses, and the discussion of records of those in the past.

Solar Activity in 1894.

The principal feature of the solar activity in 1894 as compared with 1893 has been a distinct falling off in the mean daily spotted area. December 1893 had been an exceptionally active month, the mean daily area being larger than for any other month during the present cycle, except August 1893, and the number

of distinct groups and of separate spots being even disproportionately great. The decline which was witnessed in the early days of 1894 was therefore the more marked, and except for the appearance of a specially fine group towards the end of February, that decline continued until the end of March. A revival then set in, and the next four months showed very nearly as heavy a record as any similar period in 1893. From the end of July, however, a second decline has been manifest, and has continued with irregularities, to the end of the year.

There has also been a continuance of the decline in latitude already noticed in the previous year, and the southern hemisphere has maintained the predominance over the northern which had been a marked feature of 1893.

According to the figures given by Professor Tacchini, the area of the sunspots in 1894 was about 74 per cent. of that in 1893; according to M. Guillaume's results the proportion was as high as 87 per cent. Both agreed, however, that the faculæ of 1894 were only slightly inferior in extent to those of 1893, being over 90 per cent. The crest of the curve, therefore, appears to have been definitely passed, though both sun spots and faculæ still exceed considerably, both in number and area, the record for the maximum year of the previous cycle.

Solar Spectroscopy.

At the meeting of the British Association at Oxford Professor Langley gave an account of his new methods for exploring and mapping the lines in the vast region of the solar spectrum which lies beyond the reach of the photographic plate in the infra red, and which, as is well known, has been rendered accessible for detailed study by the invention of the bolometer some fourteen years ago.

By the old method of working two observers at least were necessary, one to record the deflections of the recording galvanometer, and the other to read the angle determining the position in the invisible spectrum, whence any given thermo-electric disturbance arose. This process—which has been aptly described by Professor Langley as "a groping in the dark"—has now been entirely superseded, and a new and vastly improved form of apparatus has been constructed for the purpose of *automatically* recording with a high degree of accuracy both the intensity of any radiation falling upon the delicate bolometer thread and its wave-length.

In the new design the mirror attached to the needle of the galvanometer reflects a ray of light on to a photo-sensitised film, to which a vertical movement is given by clock mechanism, so that the horizontal swings of the needle are permanently impressed in the form of a curve on the film. The same

mechanism imparts a synchronous movement of slow rotation to the large rock salt prism, which forms the dispersion piece. In this way the entire spectrum is made to slowly drift past the bolometer thread (placed parallel with the lines in the spectrum), and the extremely sensitive galvanometer, which will betray a change of temperature amounting to only one-millionth of a centigrade degree in the thread, instantly responds to every variation in the energy of the radiation absorbed by the thread, as the invisible spectrum slowly moves over it; the spot of light reflected by the mirror tracing out, meanwhile, an "energy curve" on the moving film, the ordinate to this curve being proportional to the energy absorbed, and the abscissa being a function of wave length.

By means of another automatic process these bolograph energy curves are converted into ordinary lineal spectra, and any accidental disturbances arising from variations of temperature or of transparency in the atmosphere are eliminated by taking a number of bolographs of the same part of the spectrum and combining them by a process analogous to that of composite photography. The new bolograph has in this way already disclosed to us long reaches of spectrum as crowded with absorption lines as is the visible region, and extending down to a wave length of about seven microns. The large amount of detail which the apparatus is capable of revealing may be judged from the energy curve obtained, by way of trial, with the D lines in the visible spectrum. These are well separated, and show distinctly the nickel line between them.

We are now, therefore, entering upon a new era regarding this important work—the era of interpretation. The lines having been mapped over a length of spectrum equal to something like fifteen times that of the visible region, it now remains to study the relations which these lines bear to one another and to the various absorbing media of the solar and terrestrial atmospheres.

A further development of the spectro-photographic method of studying the solar surface, has, in the hands of M. Deslandres, yielded some new and important results. The interesting revelations which followed the first application of this method by Hale in America, as well as by Deslandres at Paris, were due to the particular ray selected, with which to obtain monochromatic images—namely, the centre of the K band. In this more recent work, however, M. Deslandres has obtained images from other dark lines, as well as from bright spaces in the spectrum. He finds that when the second slit of his spectro-heliograph is adjusted on some other dark line, or a little to one side of the centre of the K band, so as to avoid the bright reversals in the centre, but still keeping within the broad shade of that line, an image is obtained in which the faculæ are shown as clearly in the centre of the disc as near the limb; but they are less bright and less extensive than when the centre of K is used, and appear to correspond more closely with the faculæ as ordinarily seen, for the spots and penumbræ, so frequently veiled by the calcium radiation, are

well defined in these images, which are really images of the "reversing layer" between the chromosphere and photosphere.

It appears also that the smoke-like matter causing the general absorption near the limb must be situated below this layer, since these images are unaffected by it.

Monochromatic photographs obtained with the second slit adjusted on a bright space in the spectrum give images practically the same as by direct photography.

A detailed study of the double reversals of the H and K lines by the same investigator has revealed a curious want of symmetry between the bright and dark components of these lines in the general light of the sun. Thus, in 186 separate photographs of this region of the spectrum 120 clearly show a slight relative displacement between the central absorption line and the two edges of the broad and bright reversal on which the former appears to be projected. The bright edge on the side towards the red being in all these cases less distinct than the other edge, thus giving the central dark line the appearance of displacement towards the red. In spectra obtained from sections of the disc the two components of the reversal are sensibly equal in the brighter faculous region and also near the limb, but in all other parts of the disc this inequality prevails, the component on the red side being sometimes entirely absent.

In his persevering attempts to photograph the corona in full sunshine Professor Hale has again had to contend with discouraging circumstances. His latest experiments have been carried out on the summit of Etna.

The dark line K was selected by Professor Hale as the most suitable line for this work, although any other line might have served. Thus the line which has yielded such interesting results in photographing the chromosphere has again been pressed into service for the corona, but for a different reason.

Unfortunately at no time during Professor Hale's stay upon Etna were the atmospheric conditions so favourable as he had been led to expect, and the photographs he obtained show no evidence of true coronal forms. But this negative result will probably only lead to fresh efforts on his part to solve this interesting problem. J. E.

The Effective Temperature of the Sun.

Hitherto the chief investigators in this line have been Chatelier and Rosetti. The former deduced the effective temperature of the sun by measuring the photometric intensity of the red light from solid bodies heated to different known temperatures, and obtaining an empirical law which held approximately between 700° and 1800° C. This method is to a great extent vitiated by the fact that the absorption by red glass probably decreases as the radiation increases, and that in calculating the

whole energy it is not well to experiment solely with a group of wave lengths. Rosetti found a law of radiation which held well up to 2000° C, and measured in arbitrary units the heat radiated from an incandescent body at a known high temperature by means of a thermopile and galvanometer, and compared it with the heat coming from the sun by the same means. His empirical formula was $y=aT^2(T-\theta)-b(T-\theta)$, where y is the thermal effect of the radiation as given by the deflections on the scale of the thermopile, T is the absolute temperature of the radiating body, and θ that of the surrounding medium. This equation approximates to a law of the third power for very high temperatures. MM. Wilson and Gray, by employing a Joly's meldometer and a Boys' radio-micrometer, arrived at results which are more accurately given by a law of the fourth power. The result gives the effective temperature of the sun as 6200°C.; or, utilising the researches of MM. Wilson and Rambaut on the absorption of heat by the sun's own atmosphere, approximately 8700°C. Later experiments by MM. Wilson and Gray point to the fact that the same law does not hold for blacked and bare platinum, and this will probably influence the determination of the sun's temperature by a few hundred degrees. A. S. D. R.

The Transit of Mercury.

The transit on November 10 was well observed in America, and a few observations were also secured elsewhere, even in the British Isles, though ingress occurred very shortly before sunset. The observers with great unanimity failed to see any ring of light round the planet, white spot on the disc, or satellite, and almost the only noteworthy remark is made by Professor Young, who has on this and three previous occasions noticed a peculiar "hardening" of the Sun's limb just before external contact, which "may be due to the planet's obscuration of the brightest part of the chromosphere close to the disc of the Sun, or to some diffraction effect at the limb of the planet."

The German Heliometer Observations of the Transits of Venus, 1874 and 1882.

Dr. Auwers has published volume v. of the series devoted to these observations. In previous volumes the observations themselves have been given; in this the final discussion is made. The first fourteen chapters (459 pages quarto) deal with the determination of the instrumental constants, division errors, screw errors, temperature corrections, zero of focus, scale value from stars, &c. The main results of chapters xv. and xvii., which deal with the measures of diameter of the Sun and *Venus*, were published some time ago, and were noticed in the Council

Report for 1892 (*Monthly Notices*, lii. p. 279). Chapter xii. deals with the Meridian places found specially at a large number of observatories, and places in existing catalogues, of a number of stars measured by the heliometers for scale value; and the comparison of material collected from so many sources, conducted with Dr. Auwers's well-known skill, is of great value, independently of this particular research.

The discussion of the actual observations of the transits of *Venus* is contained in chapter xvi. (113 pages), and the final parallax deduced from the two transits is $8''{\cdot}896 \pm 0''{\cdot}0216$.

The Recent Opposition of Mars.

Although the greatest apparent diameter of *Mars* was less in 1894 than in 1892, being only $21''{\cdot}7$, as compared with $24''{\cdot}8$, yet the planet was much more favourably placed for observers stationed in our northern hemisphere, it having considerable north declination. So that, judging from the accounts already published, it is probable that the results obtained will equal, if not surpass, those of any preceding opposition in importance. Some of the chief points concerning the work of the past opposition may be shortly enumerated as follows:

1. The complete disappearance of the south polar spot as a visible object.

2. Numerous observations of irregularities at the terminator of the planet when it was gibbous, consisting of (*a*) small bright projections, usually in connection with a bright region just within the terminator. (*b*) Flattenings or slight hollowings of the curve of the terminator, generally at those parts where the darker regions were passing out of sight.

3. A very general confirmation of the canal system of Schiaparelli.

4. The duplication, or gemination, of a number of the canals, even at about the time of the summer solstice of the southern hemisphere.

5. Further extension of the work of Schiaparelli by the detection, chiefly at Mr. Lowell's observatory, of many additional canals and other delicate details, and of a number of minute dark spots or lakes, the latter often being curiously situated at the points where two or more canals meet or cross each other.

6. One of the most important results of the past season is certainly that relating to the presence of cloud. During recent years the opinion seems to have been gaining ground that the atmosphere of *Mars* is almost free from clouds, and that even when visible they are not of any great extent or density. But during the latter half of October last nearly the whole of the Maraldi Sea, and the extensive continental area extending north of it up to about 20° north latitude, were densely obscured by

cloud, the region affected having an area of at least 6,000,000 square miles, considerably greater than that of the whole of Europe.

7. Additional evidence in favour of actual change. For instance, the disappearance of a considerable part of the bright region named Aurea Chersonesus has been independently noted by several observers, the continental outline here being much changed from what it was in 1877, according to the maps of Mr. Green and Professor Schiaparelli.

8. Professor Campbell undertook some observations of the spectrum at the Lick Observatory, but did not succeed in confirming the earlier observations of Huggins, Rutherfurd, Vogel, and others in finding evidence of absorption due to an atmosphere.

A. S.-W.

Jupiter.

The fifth satellite remains so far the property of the discoverer that the only measures of it published during the year have been those by him. He has, however, kept a careful watch upon it, and the collected observations published in No. 325 of the *Astronomical Journal* afford material for a good determination of the orbit. The periodic time deduced is $11^h\ 57^m\ 22^s{\cdot}618 \pm 0^s{\cdot}013$; and is thus satisfactorily confirmed by the observations of Dr. Herman Struve at Pulkowa, in 1893 October (*Ast. Nach.* No. 3200), who deduced a period of $11^h\ 57^m\ 22^s{\cdot}58$ from an observed East elongation, compared with Marth's Ephemeris. Dr. Struve could recognise the satellite up to 5″ from the limb, but Professor Barnard has not recorded *measures* within 11″ of the limb. In the exhaustive paper above referred to, Professor Barnard deduces a mean distance from East elongation only during 1893, of $47''{\cdot}785 \pm 0''{\cdot}044$, at the geocentric distance 5·20 of *Jupiter*. No observations could be obtained at West elongation during 1893, but seven series were obtained in 1892, giving a mean distance $47''{\cdot}712 \pm 0''{\cdot}176$, as compared with $48''{\cdot}104 \pm 0''{\cdot}061$ from fourteen East elongations in 1892. Professor Barnard concludes that the orbit is really eccentric; and M. Tisserand has shown that the major axis must make a complete revolution in about five months. In *Ast. Nach.* No. 3267, Professor Barnard gives eight observations at West elongation on 1894 October 8, which are "the only observations he has been able to secure, though the satellite has been seen at another time; at these measures it was extremely faint." The discoverer proposes to retain the name Satellite V, remarking that if the order of discovery instead of that of distance from *Jupiter* be regarded as the criterion, the numbers I., II., III., IV., V., are probably consistent. In measuring the satellite he has incidentally measured the diameters of *Jupiter*, and finds for the

Equatorial diameter	$38''{\cdot}522$	(at Δ 5·20)
Polar diameter	$36''{\cdot}112$	„

which are about 1″ greater than heliometer measures. This systematic difference he attributes to the faulty nature of the images formed by half an object-glass in the heliometer.

Professor Newcomb has discussed* the orbit of Polyhymnia (33) and the mass of *Jupiter*, and finds for the reciprocal the mass 1047·34, which agrees well with the weighted mean (1047·35 ± 0·065) of all existing determinations.

At the end of 1893 Professor Barnard found the first satellite of *Jupiter* to have dusky poles and a bright equatorial belt,† thus confirming and explaining a previous observation in 1890, when the satellite was seen elongated. This discovery, indeed, seems to be a satisfactory explanation of several previous and mutually contradictory observations. The satellite has been announced as *ellipsoidal*, or as *double*. It is easy to see how an imperfect appreciation of the facts as now announced by Professor Barnard might lead to these interpretations of what was seen.

The Satellite of Neptune.

Dr. Hermann Struve's observations and their discussion form the subject of a memoir in Volume xlii. of the *Memoirs of the Imperial Academy of Sciences*, St. Petersburg. The observations extend over the period 1886-1893, and were made in such a manner as to exclude as far as possible systematic errors of personality and methods of observation. Thus, in measuring the position angles, he resorted to three different methods: (1) by the use of a single bright wire in a dark field; (2) a dark wire in a bright field; (3) two close parallel wires; further, he always so arranged that the line joining the planet and satellite should be either parallel or at right angles to the line joining his two eyes. The use of a single wire proved the more accurate. To make the mean times of observation in angle and distance coincident, the angles were observed in two sets, the distances being intermediate. These methods in connection with observations of twenty double stars made for the purpose, form groundwork for a thorough investigation of systematic errors. The distances were also examined thoroughly. The powers used were 515, 630, and 900.

For discussion of the observations they were divided into four groups, giving eight groups of equations (the polar formulas of Marth) and corrections to the assumed elements deduced from each series independently, the accordance of the results being eminently satisfactory. For instance, the values of the mean distance of the satellite are—

* *Ast. Nach.* No. 3249. † *Monthly Notices*, liv. p. 134.

1887·62	$a = 16''\cdot285 \pm 0''\cdot028$	
1889·02	$16\cdot272 \pm \cdot019$	
1890·61	$16\cdot253 \pm \cdot021$	
1892·60	$16\cdot203 \pm \cdot032$	

In deducing the mean motion of the satellite in its orbit, and also the motion of the plane of the orbit, Dr. Struve has used observations by Lassell, Bond, and O. Struve. The motion of the node which was first pointed out by Mr. Marth in vol. xlvi. of the *Monthly Notices* is confirmed, and Dr. Struve finds that the old and new determinations can be represented by—

$$N = 185^\circ\cdot15 + 0^\circ\cdot148\,(t-1890)$$
$$I = 119\cdot35 - 0\cdot165\,(t-1890)$$

where N is node on equator and I the inclination. This motion, M. Tisserand points out, could well be accounted for by supposing a polar compression for the planet of $\frac{1}{100}$.

The elements of the orbit are—

Longitude of Satellite reckoned from the node... ...	$234^\circ\cdot42$
Mean daily motion	61·25748
Node (referred to equator)	$185\cdot15 + 0^\circ\cdot148\,(t-1890)$
Inclination (referred to equator) ...	$119\cdot35 - 0\cdot165\,(t-1890)$
Semi-axis major (at distance whose log is 1·47814)	$16''\cdot271 \pm 0''\cdot012$
Eccentricity	less than 0·01

The orbit is thus very nearly circular.

As incidental to the chief work, Dr. Struve finds—

(1) Mass of Neptune	$\frac{1}{19396 \pm 43}$	
(2) Diameter of Neptune—yellow field		$2''\cdot120$
	Bright red	2·197
	Dark red	2·273

Professor Barnard has published (*Astronomical Journal*, No. 314) his observations of the satellite with the Lick telescope during the opposition of 1893-4.

T. L.

Double Stars.

The Society showed its appreciation of this branch of astronomy by presenting, in February 1894, its Gold Medal to Mr. S. W. Burnham for his discoveries, micrometric measures, and general work in connection with it. Since then Volume II. of

the Lick Observatory Publications has been issued, wherein is collected a great proportion of Mr. Burnham's recent work. It is a large and well-arranged volume and, from the following selected contents, is readily seen to be essential to double-star workers :

(*a*) Frontispiece showing the micrometer used with the 36-inch refractor.

(*b*) Measures of planetary nebulæ.

(*c*) Burnham's 14th, 15th, 16th, 17th, 18th, 19th catalogues of new double stars.

(*d*) Micrometer measures of known doubles.

(*e*) Work on star orbits.

Another publication which is welcome, both for its contents and its speedy issue, is Professor S. Glasenapp's "Observations Astronomiques faites à Abastouman," from 1892 August to 1893 May. These observations are in continuation of those made at Hoursouf. This is the second occasion on which Professor Glasenapp has journeyed southwards to secure the much-needed observations of southern doubles. There are 1220 measures of 610 pairs. The volume also contains such incidental work as occultations, lunar eclipse 1892 November 4, places of Comet Holmes, estimations of the variable stars *ν Arietis*, *β Lyræ*, *μ Aquilæ*, *Algol*, &c.

The only other collection of measures is that of 117 pairs made at the Royal Observatory, Greenwich, with the $12\frac{3}{4}$-inch Merz refractor, and published in the *Monthly Notices* 1894 March.

Amongst the works on double stars are Professor A. Hall's "Résumé of Different Methods of Computing Double-star Orbits" in the *Astronomical Journal* 1894 August 16 ; Professor W. Schur's "Re-determination of the Orbit and Parallax of 70 *Ophiuchi* (parallax $0''{\cdot}286 \pm ''{\cdot}031$)," "A Method of Computing a Double-star Orbit from Spectroscopic Observations of Motion in the Line of Sight," by Lehmann Filhés, in the *Astronomische Nachrichten*, 2242. Then Mr. Burnham's paper in *M.N.* 1891 April has called forth the pamphlet "Ueber den Vierfachen Stern *ζ Cancri*," in which Professor Seeliger * collects all the recent measures of this system, and shows that the undulatory motion of the distant companion C is still in evidence, and contends that no hypothesis of systematic errors due to personal equation can account for the recurrence of four revolutions (18-year period). At Georgetown College a year was spent in experimenting with a photochronograph attached to a 12-inch refractor, the object being to obtain a number of photographic images of a pair on a plate and also to derive at once a scale value. Fifteen pairs were thus photographed. These were wide pairs, and the labour involved seems scarcely to be repaid by the result.

* A translation of this will be found in *Astronom yand Astro-Physics*, 1894 December.

The orbits computed during the year are—

Star.	Period (In Years).	Computer.	Where Published
0Σ 82	90·54	J. E. Gore	*M.N.* 1894 June.
0Σ 224	96·13	J. E. Gore	*Astronomy and Astro-Physics*, 1894 Aug.
β 101	23·33	S. Glasenapp	*M.N.* 1894 March.
β 416	27·66	S. Glasenapp	Roy. Soc. N.S. Wales, 1894 June 6.
70 Ophiuchi	88·40	W. Schur	A.N. 3220–21.
η Cassiopeiæ	208·1	T. Lewis	*M.N.* 1894 November.
Sirius	50·99	C. P. Howard	*Astronomy and Astro-Physics*, 1894 June.
Sirius	51·97	S. W. Burnham	Vol. II. Lick Publications.
κ Pegasi	11·37	S. W. Burnham	„ „ „
τ Cygni	36·5	S. W. Burnham	„ „ „

T. L.

Nova Normæ.

A very interesting light was thrown upon the enigma offered by *Nova Aurigæ* by the discovery on one of the plates taken in the course of the Southern Spectroscopic Survey of Professor E. C. Pickering, of a new star bearing a striking resemblance in its spectrum characteristics to the earlier spectrum shown by *Nova Aurigæ*. The plate on which this new stellar spectrum was first seen was taken at Arequipa on 1893 July 10, and the spectrum detected by Mrs. Fleming during her examination of the plate at Harvard College on 1893 October 26. The star had been of about the 7th magnitude on July 10, and plates taken of the same region a few weeks earlier show that it could not have been as bright as the 14th magnitude on May 27, nor as the 10th on June 21. It must therefore have attained its brightness pretty rapidly. It had diminished greatly in brightness before direct visual examination could be begun, and it was only of the 10th magnitude when Professor Campbell examined its spectrum in February and March 1894. Professor Campbell's observations led him to conclude that just as its first spectrum resembled that of the first spectrum of *Nova Aurigæ*, the lines of the hydrogen series being seen double, a bright line and a dark side by side, so now, as in the case of *Nova Cygni*, its spectrum had become distinctly nebular. The importance of this is the probability it affords that both *Nova Aurigæ* and *Nova Cygni* are typical "temporary" stars even in their most characteristic details of spectrum. The place of the star for 1900 is R.A. $15^h\ 22^m\ 12^s$, Decl. 50° 13′·8 S.

Lockyer's Photographic Spectra of some of the Brighter Stars.

An important memoir on the above subject was laid before the Royal Society by Professor J. Norman Lockyer in 1892 November, and published about a year ago. The work to which it related included the taking of 443 photographs of 171 of the brighter stars. The method adopted was in the main that of the object-glass prism, the aperture usually employed being no more than 6 inches. With a prism of 45° exquisite photographs were obtained, giving spectra two inches in length from F to K, which bore a high degree of enlargement very satisfactorily.

The discussion of the photographs leads to their classification in four orders: (1) Spectra with no marked continuous absorption in the ultra-violet or violet; (2) Spectra where the absorption is marked in the ultra-violet, and extends to K; (3) Spectra where it extends to G; and, (4), four other stars, γ *Cassiopeiæ*, β *Lyræ*, P *Cygni*, and *Nova Aurigæ*. The classification is further extended to subdivisions of these orders, characterised by differences in the appearance of the principal lines, and tables are given of the wave-lengths of the strongest lines observed. The deductions Professor Lockyer draws from these photographs are in support of his Meteoritic hypothesis, and especially of his contention that there is evidence of the existence of stars of increasing temperature, as well as of decreasing. A number of reproductions of the very beautiful photographs obtained in the course of the work accompanies the paper.

The Spectra of β Lyræ and δ Cephei.

The many recent investigations of the spectrum of β *Lyræ* may be regarded as supplementary to those on *Nova Aurigæ*, the analogy between the two objects being so close that legitimate conclusions regarding one might pretty safely be extended to the other. The most important of these researches was conducted at Potsdam. It was based upon 144 spectrograms obtained by Dr. Wilsing with the International photographic telescope. The plates employed being sensitive up to λ 380, showed, for the first time, the ultra-violet part of the spectrum, which included all the more refrangible hydrogen lines, dark and bright. The solar prominence line, K, was also brilliant with a dark duplicate. The components of these and other coupled lines shifted their relative positions coincidently with the star's light-change, yet with evident outstanding disturbances, possibly comprised in a period extending over some years. Dr. Vogel's elaborate discussion of the subject was presented to the Berlin Academy of Sciences on 1894 February 8.

The Potsdam photographic results are in most satisfactory agreement with Professor Keeler's visual observations made with

the great Lick refractor in 1889, but only published in *Astronomy and Astro-Physics* for 1893 April. They related chiefly to the D_3 line. They proved besides that the variability of *β Lyræ* depends upon the fading and brightening of its continuous spectrum.

M. Bélopolsky's investigation appeared in the *Memorie degli Spettroscopisti Italiani*, for 1893 June, *t.* xxii. It is distinguished by some special features; first, the plates used being orthochromatic, the portion of the spectrum examined stretched from D to Hγ. Next, the twenty-five plates discussed were exposed with the Pulkowa 30-inch refractor. Finally, and above all, a comparison-spectrum of hydrogen, iron, or sodium, was photographed simultaneously with the star's spectrum. Absolute measurements from the fiducial lines thus afforded appeared to assign nearly the whole of the motion-displacements to the bright lines, the shiftings of which to and fro are performed as nearly as may be synchronously with the general light-change—that is, in a period of 12·9 days. The phases of the hydrogen F are noted by Dr. Vogel to be in complete accordance with those of Hζ, the ultra-violet line in which they are most characteristically marked.

Father Sidgreaves, in a paper inserted in the *Monthly Notices* for 1893 December, derived confirmatory results from forty-five spectrograms taken with the old eight-inch refractor of the Stonyhurst observatory. It appeared to him that the bright lines are at their maximum strength during the first three days after the principal minimum.

Prof. Norman Lockyer, on the contrary, regarded them as brightest soon after the secondary minimum. The materials for his research were furnished by forty-five spectrograms of *β Lyræ* taken at South Kensington with a six-inch object-glass prism fitted to a telescope of the same size; and a summary of its results, having been first communicated to the Royal Society, was published in *Astronomy and Astro-Physics* for 1894 August. The photographs showed: (*a*) periodical changes in the relative intensities of the lines; (*b*) periodical doublings of some of the dark lines; (*c*) periodical changes in the positions of the bright lines with respect to the dark ones. He inferred the presence of two bodies giving dark-line spectra, the greatest relative velocity of which in the line of sight is about 156 miles a second; and, further, the strong resemblance of one of these to *Rigel*, and of the other to *Bellatrix*. Shifting bright lines are superposed upon the double absorption spectrum; but all spectral variations bear a constant relation to the general period of the star.

Prof. Lockyer, as well as M. Bélopolsky and Father Sidgreaves, account for the two-fold obscuration of *β Lyræ* by partial eclipses occurring when the two bodies believed to compose it are situated in the line of sight from the Earth. But, according to Dr. Vogel and Professor Keeler, an eclipse-hypothesis is negatived by the fact that at the epoch of principal minimum, the coupled lines

are at their maximum of separation. In other words, the stars, instead of being in conjunction, are at elongation. Thus, the problem presented by this star remains for the present unsolved. Its interest has, if possible, been heightened by M. Bélopolsky's announcement (*Astr. Nach.* No. 3257) that δ *Cephei*, too, is a spectroscopic binary, completing its revolutions in the identical period of its light-phases. His results, however, are to be regarded as only provisional. All short-period variables may, perhaps, before long come to be regarded as multiple systems.

A. M. C.

Star Catalogues.

On his return from the Cape of Good Hope and appointment to the Directorship of the Radcliffe Observatory, Oxford, Mr. Stone determined to carry into the northern hemisphere the general survey of the stars which he had completed for the southern hemisphere in his *Cape Catalogue*, 1880. For fourteen years (1880 January 1 to 1893 December 31) the transit-circle of the Radcliffe Observatory has accordingly been devoted to the observation of stars to about the seventh magnitude, distributed over the northern hemisphere, and the result is a catalogue of 6424 stars between the North Pole and 115° south declination, some being included which are a little further south. There are roughly 29000 square degrees in the portion of the heavens surveyed, giving an average of rather less than one star to a photographic plate (four square degrees) as planned by the International Conference. Such a comparison reminds us of the magnitude of the astrographic scheme.

The epoch of the catalogue is 1890. Proper motions have been deduced in all cases, where comparison with previous catalogues shows them to be large, and the reference numbers to six such catalogues, commencing with Bradley (1755) and ending with Greenwich (1880) are given. In a brief introduction, Mr. Stone points out that the systematic errors of the catalogue cannot be large.

Observations of the Sun have been made during the years 1884–91, and discussed separately year by year, as well as by grouping the whole series; and an epoch correction of $+0^{s}\cdot014$ adopted. The flexure, as determined by the horizontal collimators, was very steady, the coefficient being confined within the limits $1''\cdot25$ and $1''\cdot10$. A discussion of circumpolar observations affords evidence for a slight diminution of Bessel's mean refractions, which has not, however, been applied. The correction to adopted colatitude was found insensible.

The work "owes its existence" not only to the untiring energy of Mr. Stone and the staff of the Radcliffe Observatory, but "to the liberality of the Radcliffe Trustees."

Vol. xvii. of the *Results of the Argentine National Observa-*

tory, and the twelve maps referred to in the last Report, have been published during the year.

M. Nyrén has published a Catalogue of Mean Declinations of 450 fundamental stars, observed with the Pulkowa Vertical Circle, during the years 1882–1891. The epoch of the Catalogue is 1885. A comparison with the similar Catalogue for 1865 is given in a brief introduction.

The *Cape Catalogue* (1885–90) has also been published, but has not yet been received by the Society.

A five-year catalogue of 258 fundamental stars for 1890 has been published by the Astronomer Royal, and the places used in the *National Almanac* for 1896.

A volume of the Revision of the *Durchmusterung* has been published by the Bonn Observatory (+40° to +50°, 18457 stars).

Spectroscopic Observations of Nebulæ.

An important paper by Professor Campbell on the spectra of the *Orion* and other nebulæ, appeared in *Astronomy and Astro-Physics* for May last. Professor Campbell gives tables of bright lines photographed in the *Orion* nebula, of dark lines photographed in *Orion* stars, and of the comparison of bright nebular and dark star lines. He comes to the conclusion that "nearly all the dark lines in the faint stars are matched by bright lines in the nebula, but there is no reason known at present for supposing that the prominent nebular lines λ5007, λ4959, λ4346, λ3869, λ3727 are matched by dark stellar lines. They appear to remain characteristic of the nebular spectrum. The fact that some or all of these positions are not occupied by dark lines renders it doubtful whether any of the lines are due to absorption by the nebula proper, and we cannot say that these stars are beyond the nebula or are physically connected with it. We may say that they are closely related to the nebula in chemical constitution, and relatively closely in physical constitution."

In the continuation of this paper Professor Campbell gives the results of visual and photographic observations of six planetary nebulæ, combining the whole result in a table which gives in parallel columns the bright lines of the *Orion* nebula, and of the planetary ones. "The prevalence," he says, "of the same lines in these nebulæ is very noticeable, and it would be found to be much more general if the nebulæ were more nearly of the same density, so that equivalent exposures could be made." There are a few points of correspondence between the nebular spectrum and that of the Wolf-Rayet stars, but there are so many points where correspondence is lacking that we cannot say the two types are closely related.

Professor Keeler's spectroscopic observations of nebulæ made at the Lick Observatory have appeared in full in the last volume

of the *Publications* of that observatory, The following are the principal conclusions at which he arrives :

1. The normal position of the chief nebular line is λ5007 ±0·03 on Rowland's scale.

2. The normal position of the second line is λ4959·02±0·04. This line is 1·39±0·04 tenth-metres less refrangible than the centre of the double line of iron at λ4957·63.

3. The first and second nebular lines are not represented by absorption lines in the solar spectrum, as shown in Rowland's map.

4. The relative brightness of these two lines is, within the limits of error of estimation, the same for all nebulæ. Hence there is reason for thinking that they are due to the same unknown substance, perhaps an element of somewhat the same nature as the so-called helium.

5. The spectrum of the bright line nebulæ indicates either a high temperature of the gases emitting the light, or a state of strong electrical excitement, and shows that the temperature and pressure are greatly increased at the nucleus.

6. The distance between the great nebula of *Orion* and the Sun is increasing at the rate of 11±0·8 miles per second.

7. No relative motion of different parts of the *Orion* nebula could be detected.

8. The nebulæ are moving in space with velocities of the same order as those of the stars. Of the nebulæ observed, G.C. 4373 has the greatest motion of approach, namely, 40·2 miles per second ; and N.G.C. 6790 the greatest motion of recession, 30·1 miles per second.

10. The visible spectrum of the nucleus of a planetary nebula has in many cases a resemblance to that of stars of the Wolf-Rayet class, though the two principal nebular lines are absent from the latter.

In a paper on the continuance of his observations on the spectra of nebulæ made at the Allegheny Observatory, Professor Keeler gives a table of the wave-lengths of the bright lines measured on photographs of the spectrum of the *Orion* nebula, and a second table of the positions of the dark lines in the spectra of the trapezium stars, also of the lines in the lower spectrum of *Rigel*. He discusses at length a comparison of the bright nebular lines with the dark lines in the spectra of the *Orion* stars, and concludes that these demonstrate the intimacy of the relation which exists between the *Orion* nebula and the neighbouring stars—indeed, "the spectrum of *Rigel* may almost be regarded as the nebular spectrum reversed." According to Professor Keeler, while the relation to the nebula of the trapezium stars is more certain than ever, they can no longer be regarded as necessarily situated in the nebula. The broadness of the hydrogen absorption lines precludes the supposition that the absorption is due to the nebula itself, and the stars may therefore, within indefinite limits, be placed anywhere in the line of sight.

The Potsdam Photometry.

The most recent and most complete of modern researches on the visual magnitude of the stars has lately been brought to the conclusion of its first stage. Doctors Müller and Kempf, of Potsdam, have published* their observations of the brightness of all stars in the zones 0° to +20° declination whose magnitude is not recorded as fainter than 7·5 in Argelander's Durchmusterung, 3522 stars in all. Within a few years they hope to complete this survey to the North Pole. The photometer chosen is that of Zöllner, three different instruments adapted to stars of different brightness being used. A list of 144 fundamental stars well distributed throughout the sky was first prepared and the determinations of their brightness carried to an extreme degree of accuracy, discussions being made of the influence of colour in the star and of personality in the observer. With these as reference points, the general mass of the stars was examined in short zones of twelve stars each, a pair of standard stars being measured at the beginning, in the middle, and at the end of each zone; the magnitude of every star was determined once by each observer, and the accordances are so close as to justify the observers in regarding their work as a considerable advance not only in scope but in accuracy on anything that has been done before. The final catalogue of 3522 stars gives a reference to the B.D., the R.A. and declination for 1900, the B.D. mag., the separate determinations by the two observers, with references to the zones where their original observations are to be found, a compendious note on the colour of the star, and other remarks of interest. The arrangement of the work leaves, in fact, nothing to be desired in the way of completeness and facility of reference Finally a comparison is made between the present work and the Oxford and Harvard Photometries, cases of large discordance being carefully noted.

The Astrographic Chart.

As no *Bulletin du Comité Permanent* has been published during the year, all our information on the progress of the photographic mapping of the heavens is derived from a few scattered notices and reports of observatories. Seven of the associated observatories have already taken more than half the number of catalogue plates assigned to them. There is every reason to hope that all the photographs for the catalogue—with the possible exception of those allotted to the South American observatories—will be completed in two or three years time. The number of chart (long exposure) plates taken is, however, much smaller, and at the present rate of progress, this part of the work

* *Potsdam Observatory Publications*, vol. ix.

will not be completed by 1900. No reproductions of the plates have yet been published.

In the work of measuring the catalogue plates the French observatories have taken the lead. At the beginning of the year seventy-two plates had been measured at Paris and thirty-eight at Algiers, and the work is in full progress. Several other observatories have begun this laborious task, but there are at present no means for assigning even an approximate period for its completion. During the year a memoir has been published by M. Anders Donner, on the reduction of the measures of the Helsingfors plates; and two notes have appeared in the *Monthly Notices* in which the simple linear method of reduction given by Professor Turner in 1893 November, is practically applied.

We report with regret the deaths of Father Denza and M. Maturana, directors respectively of the observatories of Rome and Santiago, both of which are co-operating in the work of photographing the heavens. F. W. D.

Astronomical Photography.

The rapidly increasing importance of the photographic method would seem to make it especially desirable to summarise the history of the year. There is, however, a peculiar difficulty in so doing. The questions of the systematic reproduction of photographs, and of the form in which measures, made on plates which it is not intended to reproduce, shall be given, are not yet settled; and anything like a complete knowledge of what has been done during the year is thus almost impossible. In future Reports of the Council it is hoped to deal more fully with such a summary. For the present it may be mentioned that in volume iii. of the *Lick Observatory Publications*, there are some beautiful enlargements of lunar photographs taken with the 36-inch refractor, stopped down to 8 inches; that Dr. L. Weinek, who made the enlargements, has also published some equally fine enlargements of lunar negatives taken by MM. Lœwy and Puiseux at Paris; that Dr. Roberts has published his photographs of star clusters and nebulæ, which are referred to elsewhere; and that Professor Barnard of the Lick Observatory has sent to this Society sixty positives of stars and comets, the publication of which is under consideration by the Society.

The Council of the Society have further determined to consider fully the question of reproduction of photographs, with the view of acting as a centre for distribution of permanent copies at approximately cost price. The details are under consideration, and it may take some time to arrive at a final plan of procedure; but if the Council have rightly estimated the advantages of such a scheme, it cannot be made generally known too early. Information and advice from others will be cordially welcomed, and can-

not fail to be of the greatest assistance in organizing the systematic reproduction of photographs.

Variation of Latitude.

Several papers of considerable importance in connection with the variation of latitude have been published during the year. Mr. Chandler has reduced and discussed the observations made by Pond at Greenwich in the years 1825 to 1835 with two mural circles. "This beautiful series of observations may be regarded as one of the most remarkable in modern astronomy. Hitherto, however, astronomy has not reaped its benefits from the fact of Pond's inadequate reduction of them." Pond's device was to observe a star directly with one instrument and by reflection with the other at the same culmination, reversing the arrangement on another night. Mr. Chandler selects 7176 combinations of thirty-six stars, and after carefully investigating the systematic errors of refraction, possible temperature effect on runs, &c., uses this valuable material for determining the oscillation of latitude, which satisfactorily corresponds with his tentative hypothesis. The continuation of the series from 1836 to 1851 under Airy's directorship, though not so homogeneous, is also discussed, yielding 4353 observations. This is the last of the individual series of observations successively examined by Mr. Chandler, and he has proceeded to make a definitive discussion of the whole. The results may be briefly stated as follows:

There are two terms of latitude variation, whose periods are respectively one year and 428·6 days, and whose mean coefficients are equal, each being $0''\cdot135$; but both the epochs and coefficients of these terms are affected by a slow oscillation in a period of about sixty or seventy years, the amplitude of the oscillation for the 428-day term being about $0''\cdot1$, and of the annual term about $0''\cdot05$; it is suggested that the pole rotates, not in a circle, but in an ellipse with revolving apses; this suggestion receives support from the discussion of the observations between 1889 and 1894, during which years special observations have been made under the direction of the International Geodetic Association. A brief account of the special series at Kasan and Karlsruhe and at Strassburg and Bethlehem was given by Dr. Förster at the meeting of the British Association at Oxford, and the full report by Professor Albrecht has been published. Some valuable observations were also made at San Francisco by Professor Geo. Davidson. Mr. Chandler's papers are printed, as before, in the *Astronomical Journal.*

New Observatories.

Recently several new Observatories have been established and changes made in others. Mr. Percival Lowell, a citizen of Boston,

has built an observatory for himself, longitude 112° W., latitude 35° N. in the territory of Arizona, near the town of Flagstaff, at an elevation of 7300 feet above the sea. This site is said to be higher than that of any large observatory in the Northern hemisphere. The equipment consists mainly of two telescopes with object glasses, respectively of 18 inches and 12 inches aperture, mounted as a twin instrument on an equatorial mounting. It is purposed to use the larger of these for spectroscopic and general eye observations, and the smaller for photography. The scheme of work laid down by Mr. Lowell for the observatory is chiefly the examination of planetary detail, and he and his assistants, Professor W. H. Pickering and Mr. Douglass, have published extensive reports of observations of *Mars* in recent numbers of *Astronomy* and *Astro Physics*. Another of the institutions referred to above is the Manora Observatory, Lussinpiccolo, Austro-Hungary, under the direction of Herr Leo Brenner, who has for his use a 7-inch refractor by Reinfelder and Hertel, with which he observes the details of lunar and planetary surfaces.

The Dudley Observatory, Albany, U.S.A., which was established in 1857, under the direction of Dr. B. A. Gould, has recently been transfered to a new site. Several reasons, among which was the proximity of a railroad, conspired to make the transference advisable, and a liberal donation by Miss Catherine Bruce, together with the proceeds of a public subscription, provided funds for building a new observatory on a site given by the City of Albany in exchange for the former grounds and buildings. The new site is in the western part of Albany, but its geographical coordinates are not known with great certainty. The adopted longitude of the transit circle is $4^h\ 55^m\ 6^s{\cdot}8$ W., latitude 42° 39′ 12″·7 N. The old observatory was abandoned in June 1893, at which time the new buildings were nearly ready for use. The instruments were then transferred, and were arranged ready for observation by the beginning of 1894. The transit circle is the Olcott Meridian Circle, which had been used in the old observatory since its foundation, and with which the observations for the zone-catalogue contributed by Albany to the catalogue of the *Astronomische Gesellschaft* were made. This instrument is described in the Introduction to the Albany Zone-Catalogue. A new equatorial telescope has been provided by funds supplied by the sons of the late R. H. Pruyn, formerly President of the Observatory Trustees. This telescope of 31 cm. aperture, made by the firm of Warner and Swasey, Mr. Brashear supplying the optical parts, has been actively used since 1894 March 29 for observation of position of comets and small planets.

A powerfully equipped observatory has recently been formed at Manila in the Philippine Islands, in latitude about 14° N., where there has been for some years a meteorological and seismographic observing station. The observatory is under the direction of Father Algué, and owns an equatorial having an object glass by Merz of 19·2 English inches in diameter, and provided

with a photographic correcting lens, which is to be used for photographic, spectrographic, and visual work on stars. The work immediately in hand is the making of observations for the determination of variation of latitude, in connection with similar work by Fathers Hagen and Fargis at Georgetown College Observatory. The instrument used for this at Manila is the Reflecting Zenith Telescope with two objectives, described in *Monthly Notices*, vol. liv. p. 264. No observations have yet been published from this observatory.

Dr. Lewis Swift, formerly of the Warner Observatory, Rochester, U.S.A., is now in charge of an observatory lately erected by Professor T. S. C. Lowe, Echo Mountain, Southern California, sixteen miles north-east of Los Angeles, and about 3500 feet above sea-level. The equipment of this observatory consists of the 16-inch Clark refractor and other instruments which have been used by Dr. Swift at Rochester. A noteworthy incident at this young institution has been the finding of a comet by Edward Swift, son of the director.

A note in the *Astronomische Nachrichten*, No. 3232, published in June last, announced that the Observatory at Karlsruhe was to be abandoned, and its instruments to be used in furnishing a new observatory at the University of Heidelberg, of which Professors Valentiner and Max-Wolf were to be directors respectively of the astronomical and astrophysical departments.

H. P. H.

PAPERS READ BEFORE THE SOCIETY FROM MARCH 1894 TO JANUARY 1895.

1894

Mar. 9. A seconds contact-maker for astronomical clocks. H. C. Russell.

Brilliant detonating fireball of 1894 January 25. W. F. Denning.

Remarks upon Mr. Stone's corrections to the measure of time since 1864. Professor S. Newcomb.

Note on the star DM + 27°·725. A. M. W. Downing.

On the proper motion of stars in the Dumbbell Nebula. A. A. Rambaut and W. E. Wilson.

Note on star corrections in N.P.D. W. E. Cooke.

On star corrections. Professor H. H. Turner.

Description of a perfectly achromatic refractor. H. D. Taylor.

Results of micrometer measures of double stars with the $12\frac{3}{4}$-inch Merz refractor at the Royal Observatory, Greenwich, during the year 1893. Communicated by the Astronomer Royal.

New orbit of 9 *Argûs*, β 101. Professor S. Glasenapp.

Apr. 13. Note on Professor Newcomb's remarks upon Mr. Stone's proposed corrections to the measure of time. E. J. Stone.

Occultation of *a Virginis* observed at Dunsink, 1894 March 22. Professor A. A. Rambaut.

Photograph of the cluster M. 46, and of the nebula H IV. 39 *Argûs*. Isaac Roberts.

Photograph of a "new" spiral nebula in *Perseus*. Isaac Roberts.

Photograph of the nebula H I. 156 *Persei*. Isaac Roberts.

The star cluster 3315. H. C. Russell.

Remarks on the best method of determining the positions of the planets by observation. David Gill.

Observations of Comet *a* 1894 (Denning), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Comet *a* 1894 (Denning), made at the Liverpool Observatory. W. E. Plummer.

1894 Ephemeris for physical observations of *Mars*, 1894.
April 13. A. Marth.

An experiment with a 12½-inch refractor, whereby the light lost through the secondary spectrum is separated out and rendered approximately measurable. H. D. Taylor.

Note on some photographs taken with a visual telescope. H. F. Newall.

On graduating wedges. Captain W. de W. Abney.

May 11. Note on the computation of the brightness of the planets, with some ephemerides for observations of the brightness of *Mercury*. A. Marth.

Note on the red spot on *Jupiter*. Joseph Gledhill.

Observations of the phenomena of *Jupiter's* satellites at Bermerside Observatory, Halifax, in the years 1892 and 1893. Joseph Gledhill.

Photograph of the nebulæ M. 78 and ♅ IV. 36 *Orionis*. Isaac Roberts.

Photograph of the nebula M. 74 *Piscium*. Isaac Roberts.

Two questions on Mr. Stone's proposed correction to the measure of time. Professor S. Newcomb.

The effect of personality in observations of the Sun's right ascension on the determination of the position of the ecliptic. F. W. Dyson and W. G. Thackeray.

On some possible improvements in meridian and extra-meridian observing. Professor H. H. Turner.

Note on the solar eclipse of 1598. J. L. E. Dreyer.

Note on the proper motion of the star L L 38239. J. L. E. Dreyer.

Differences of R.A. and N.P.D. of *Uranus* and 8 *Libræ* and *a Libræ* about the time of the conjunction in 1894 April, observed with the transit-circle at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Reply to Professor Newcomb's two questions on the proposed correction to the measure of time. E. J. Stone.

A new variable star of Type IV. Rev. T. E. Espin.

On the dimensions of *Saturn's* disc. Hermann Struve.

Observations of Comet *b* 1894 (Gale), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

June 8. Note on the lunar theory. Professor E. W. Brown.

The discovery of comets. W. F. Denning.

Photograph of the cluster ♅ VI. 37 *Argûs*. Isaac Roberts.

Photograph of the nebulæ ♅ V. 42 and ♅ I. 176, 177 *Comæ Berenicis*. Isaac Roberts.

1894 Photograph of the nebulæ M. 65, 66, and H V. 8 *Leonis.*
June 8. Isaac Roberts.

Note on the variable star U *Orionis.* Lieutenant-Colonel E. E. Markwick.

Comet *b* 1894 (Gale), observed at Sydney Observatory. H. C. Russell.

Orbit elements of Comet *b* 1894 (Gale). John Tebbutt.

Note on the star B.A.C. 5255 = Brisbane 5525. A. M. W. Downing.

On two distribution maps of the nebulæ and clusters in Dr. Dreyer's Catalogue of 1888. Sidney Waters.

Motions of fireballs and shooting stars relatively to the earth. W. F. Denning.

On the semi-annual variation of meteors. G. C. Bompas.

On the orbit of OΣ 82. J. E. Gore.

Remarks on Dr. Roberts's photographs of star clusters. E. B. Knobel.

On some points connected with the integration of the differential equations of the relative motions of material systems. E. J. Stone.

Note on the distribution of the stars generally used for the determination of clock-error. E. J. Stone.

Ephemeris of the satellites of *Mars*, 1894. A. Marth.

Ephemeris for physical observations of *Jupiter*, 1894–95. A. Marth.

Some measures of photographs of the *Pleiades* at the Oxford University Observatory. Professor H. H. Turner.

On the formation of photographic star-discs. H. F. Newall.

On the R — D discordance. Professor H. H. Turner and W. G. Thackeray.

Observations of Comet Gale (*b* 1894), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Comet Gale, made at the Cambridge Observatory with the Northumberland Equatorial and square bar micrometer. Communicated by Sir R. S. Ball.

Nov. 9. Note on Comet Gale (*b* 1894). W. F. Gale.

Observations of Comet *b* 1894 (Gale), made at the Cambridge Observatory. Communicated by Sir R. S. Ball.

Observations of Comet *b* 1894 (Gale), made at the Royal Observatory, Cape of Good Hope. Communicated by Dr. Gill.

Observations of Comet *b* 1894 (Gale), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

1894 Nov. 9. Micrometrical measures of the diameters of *Ceres*, *Pallas*, and *Vesta*, made with the 36-inch refractor of the Lick Observatory. E. E. Barnard.

On the proper motions of Groombridge, 1172, W.B. (2) XII. 740–1, W.B. XII. 632. A. C. D. Crommelin.

Ephemeris for physical observations of *Jupiter*, 1894–95 (concluded). A. Marth.

Note on Professor Turner's paper on the reduction of measures of photographic plates. F. W. Dyson.

Note on stars suitable for the determination of clock-errors. A. M. W. Downing.

Data for computing the positions of the satellites of *Jupiter*, 1894–95. A. Marth.

Note on the lunar theory. Professor E. W. Brown.

On the computation of star-corrections. W. H. Finlay.

Photograph of the nebulæ ♅ I. 84 ; *h* 1442; and ♅ II. 344 *Comæ Berenicis*. Isaac Roberts.

Photograph of the nebulæ ♅ I. 143 and II. 536 *Virginis*. Isaac Roberts.

Comparison of the Pulkowa Catalogue (1885) with the Greenwich Ten-Year (1880) and Five-Year (1890) Catalogues. W. G. Thackeray.

Note on the binary star *κ Pegasi* (β989). T. Lewis.

On the orbit of *η Cassiopeiæ* (Σ 60). T. Lewis.

Note on solar observations at Stonyhurst College Observatory. Rev. W. Sidgreaves.

Note on the latitude of the Royal Observatory, Cape of Good Hope. David Gill.

Preliminary note on the position of the Liverpool Observatory. W. E. Plummer.

Observations of Comet II. 1894 (Gale), made at the Liverpool Observatory. W. E. Plummer.

On the rotation and mechanical state of the Sun. R. A. Sampson.

On the effect of atmospheric dispersion on the position of a star. Professor A. A. Rambaut.

Note on Mr. Stone's theory of the measure of time. Professor S. Newcomb.

A comparison between the results of the Radcliffe Catalogue of stars (1890) and the Greenwich Five-Year Catalogue (1890). E. J. Stone.

Dec. 14. The annular eclipse of the Sun, 1894 April 6, and the solar eclipse of 1894 Sept. 29. C. Michie Smith.

The solar eclipse of 1894 Sept. 29. Captain H. G. Thomas.

Results of micrometer-comparisons of *Uranus* and *α Libræ*. John Tebbutt.

Observations of the transit of *Mercury*, 1894 Nov. 10, made at Grahamstown, Cape of Good Hope. L. A. Eddie.

1894 Observations of the transit of *Mercury*, 1894 Nov. 10.
Dec. 14. Lieutenant Basil Taylor.

On the proper motion of three stars in the constellation *Ophiuchus*. W. T. Lynn.

On the late transit of *Mercury* (1894 Nov. 10). Rev. S. J. Johnson.

Observations of the transit of *Mercury* on 1894 Nov. 10, at Sidmouth, Devon. A. F. Lindemann.

Notes on suitable stations in Norway for viewing the total solar eclipse of 1896 Aug. 8. Colonel A. Burton-Brown.

Observation of a daylight occultation of *Antares*. John Tebbutt.

Observations of *Polaris* made at the Royal Observatory, Greenwich, in the years 1836–93. W. G. Thackeray.

A comparison of some places of stars observed at the Sydney Observatory with the places of the same stars given in the Cape Catalogue, 1880. H. P. Hollis.

A re-determination of the epoch correction and mean motion for Hansen's Lunar Tables from meridian observations of the Moon, 1750–1892. E. J. Stone.

Note on Professor Newcomb's note in the *Monthly Notices* for Nov. 1894. E. J. Stone.

Account of the measurement and comparison of a set of four astrographic plates, made at the Royal Observatory, Greenwich. W. H. M. Christie and F. W. Dyson.

Remarks on three volumes of Sun-spot drawings presented to the Society. Rev. F. Howlett.

1895 Jan. 11. Observations of the transit of *Mercury*, 1894 Nov. 10, made in New South Wales. H. C. Russell.

Preliminary note on the determination of terrestrial longitudes of photography. Captain E. H. Hills.

Mean areas and heliographic latitudes of Sun-spots in the year 1892, deduced from photographs taken at the Royal Observatory, Greenwich; at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Observations of Encke's comet made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of occultations of stars by the Moon, and of phenomena of *Jupiter's* satellites, made at the Royal Observatory, Greenwich, in the year 1894. Communicated by the Astronomer Royal.

On the need and usefulness of co-operation in meridian observation. Professor T. H. Safford.

Index catalogue of nebulæ found in the years 1888–94,

1895 Jan. 11. with notes and corrections to the New General Catalogue. J. L. E. Dreyer.

On the measurement and reduction of the plates for the Astrographic Chart. Professor H. H. Turner.

Observations of comets Sawerthal, 1888; Davidson, 1889; Wolf, 1891; Holmes, 1892; Rordame-Quénisset, 1893; and Encke, 1894; made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Estimated magnitude of *Nova Aurigæ*. Communicated by E. J. Stone.

Preliminary note on a modified (Oblique) form of Cassegrain telescope. Dr. A. A. Common.

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE CONTRIBUTED TO THE LIBRARY, &C., SINCE THE LAST ANNIVERSARY.

Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The French Ministry of Public Instruction.
The Italian Government.
The Norwegian Government.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
Camera Club.
Geological Society of London.
Institution of Civil Engineers.
Meteorological Office.
Royal Photographic Society of Great Britain.
Physical Society of London.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Society of London.
Royal United Service Institution.
Society of Arts.
University College, London.
Belfast Natural History and Philosophical Society.
Birmingham Philosophical Society.
Cambridge Philosophical Society.
Cardiff, Astronomical Society of Wales.
Cork, Queen's College.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Edinburgh, Royal Observatory.
Kew Observatory.
Leeds Astronomical Society.
Liverpool Observatory.
Manchester Literary and Philosophical Society.
Oxford, Delegates of the Clarendon Press.
Oxford, Radcliffe Library.
Oxford, Radcliffe Observatory.

Rugby School Natural History Society.
Stonyhurst College Observatory.
Adelaide Observatory.
Amsterdam, Royal Academy of Sciences.
Australasian Association for the Advancement of Science.
Batavia, Magnetical and Meteorological Observatory.
Belgium, Royal Observatory.
Berlin, Physical Society.
Berlin, Royal Prussian Academy of Sciences.
Berlin, Royal Observatory.
Berne University.
Bombay Branch of the Royal Asiatic Society.
Bombay Government Observatory.
Boston, American Academy of Arts and Sciences.
Brisbane, Royal Geographical Society of Australasia.
Buda-Pesth, Royal Hungarian Institute for Meteorology and Terrestrial Magnetism.
Buenos Ayres, Argentine Meteorological Office.
Calcutta, Asiatic Society of Bengal.
Cape of Good Hope, Royal Observatory.
Cape Town, South African Philosophical Society.
Charkow, University Observatory.
Christiania, Norwegian Geodetic Commission.
Copenhagen, Royal Danish Academy of Sciences.
Cordoba, Argentine National Observatory.
Cracow, Academy of Sciences.
Delft, Polytechnic School.
Geneva, Society of Arts.
Georgetown College Observatory.
Göttingen, Royal Observatory.
Göttingen, Royal Society of Sciences.
Haarlem, Teyler Museum.
Halle, Leopold-Caroline Academy of Naturalists.
Harvard College Astronomical Observatory.
Helsingfors, Geographical Society of Finland.
Helsingfors, Society of Sciences of Finland.
Hong Kong Observatory.
India, Survey Department.
Kasan, Astronomical Observatory.
Kasan, Imperial University.
Kiel, Royal Observatory.
Leiden Observatory.
Leipzig, Astronomical Society.
Leipzig, Royal Saxon Society of Sciences.
Lick Observatory.
Lund Observatory.
Madras, Government Observatory.
Madrid Observatory.
Manila, Meteorological Observatory.
Mauritius, Royal Alfred Observatory.

Melbourne Exhibition Trustees.
Melbourne Observatory.
Melbourne, Royal Society of Victoria.
Moncalieri Observatory.
Montpellier, Academy of Sciences.
Moscow, Imperial Society of Naturalists.
Munich, Royal Bavarian Academy of Sciences.
Naples, Academy of Sciences.
Naples Observatory.
Natal Observatory.
New York Mathematical Society.
O-Gyalla, Astrophysical Observatory.
O-Gyalla, Central Meteorological and Magnetical Observatory.
Ottawa, Canadian Meteorological Society.
Ottawa, Royal Society of Canada.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.
Paris, Bureau of Longitude.
Paris, General Depot of Marine.
Paris, International Committee of Weights and Measures.
Paris, International Geodetic Association.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society of France.
Paris, Polytechnic School.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Potsdam, Astrophysical Observatory.
Prague, Imperial Observatory.
Puebla, Catholic College.
Pulkowa Observatory.
Rome, Central Meteorological Office.
Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy *dei Lincei*.
Rome, Royal Academy *dei Lincei*.
Rome, Vatican Observatory.
St. Petersburg, Imperial Academy of Sciences.
San Fernando Observatory.
San Francisco, Astronomical Society of the Pacific.
St. Louis, Academy of Sciences.
Stockholm, Royal Swedish Academy of Sciences.
Sydney, Government Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya Observatory, Mexico.
Tiflis, Physical Observatory,
Toronto, Astronomical and Physical Society.
Toronto, Canadian Institute.
Toronto University.
Toulouse, Academy of Sciences.

Trieste, Astronomical and Meteorological Observatory.
Turin, Royal Academy of Sciences.
Upsala, Royal Society of Sciences.
Vienna, Austrian Geodetic Commission.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Observatory.
Vienna, von Kuffner's Observatory.
Washburn Observatory of the University of Wisconsin.
Washington, National Academy of Sciences.
Washington, Office of the American Ephemeris.
Washington, Smithsonian Institution.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.
Yale University Astronomical Observatory.
Zurich, Central Meteorological Institute of Switzerland.
Zurich, Geodetic Commission of Switzerland.
Zurich, Natural History Society.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of the "Astronomische Nachrichten."
Editors of "Astronomy and Astro-Physics."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Indian Engineering."
Editor of "Knowledge."
Editor of the "Naturwissenschaftliche Rundschau."
Editors of the "Observatory."
Editor of the "Open Court."
Editor of "Science Progress."
Editor of "Sirius."

Sigr. F. Angelitti.
Dr. F. Anton.
Prof. A. Auwers.
Lieut. C. W. Baillie.
Prof. E. E. Barnard.
Comte de la Baume-Pluvinel.
Prof. L. Becker.
A. W. Bickerton, Esq.
Comtesse Bobrinskoy.
E. Breach, Esq.
William Briggs, Esq.
Prof. S. W. Burnham.
Prof. A. Cayley.
Sigr. G. Ciscato.
J. Cobb, Esq.
Sigr. F. Contarino.
Prof. A. Cornu.
W. Crouch, Esq.
Mons. Henri Deslandres.
Dr. W. Döllen.
Herr A. Donner.
Prof. C. L. Doolittle.
Dr. J. L. E. Dreyer.
Mons. C. Easton.
Rev. T. E. Espin.
Dr. L. Fabry.
Herr Julius Fényi.
Mons. C. Flammarion.
Prof. G. Forbes.
Dr. J. Franz.

Dr. H. Fritsche.
Prof. E. B. Frost.
Mons. A. Gaillot.
Prof. J. G. Galle.
Mons. R. Gautier.
Miss A. Giberne.
Prof. S. Glasenapp.
Herr E. von Gothard.
Herr J. H. Graf.
Sigr. L. Grandi.
Mons. J. Guillaume.
Prof. H. Gyldén.
Prof. G. E. Hale.
Dr. B. Hasselberg.
Prof. E. S. Holden.
Rev. F. Howlett.
R. Inwards, Esq.
Messrs. Isbister & Co.
B. G. Jenkins, Esq.
R. C. Johnson, Esq.
Herr A. Kammermann.
Prof. J. E. Keeler.
E. B. Knobel, Esq.
Herr S. Kostinsky.
Prof. S. P. Langley.
Henry Larkin, Esq.
Messrs. Longmans & Co.
Herr G. Lorentzen.
Sigr. G. Lorenzoni.
W. T. Lynn, Esq.
Herr Paul Martin.
Prof. Herbert A. Newton.
Sigr. A. Nobile.
A. P. Pichereau, Esq.
Prof. W. H. Pickering.
Mons. W. Prinz.
Sigr. A. Ricco.
Herr S. Riefler.
Dr. A. Riggenbach.
Dr. Isaac Roberts.
H. C. Russell, Esq.
Prof. J. M. Schaeberle.
Herr O. E. Schiötz.
Dr. R. Schorr.
Dr. W. Schur.
Prof. H. Seeliger.
R. P. Sellors, Esq.
M. C. Sharp, Esq.
Herr R. Spitaler.
John Tebbutt, Esq.
Herr A. Tischner.
Sir Charles Todd.
Mrs. D. P. Todd.
F. W. Very, Esq.
Mons. E. Vimont.
Prof. H. C. Vogel.
Herr A. Weilenmann.
Prof. L. Weinek.
Prof. W. C. Winlock.
Herr Th. Wittram.
Dr. A. Wolfer.
Prof. C. V. Zenger.

ADDRESS

Delivered by the President, Captain W. de W. Abney, C.B., R.E., D.C.L., F.R.S., on presenting the Gold Medal to Dr. Isaac Roberts.

The Medal of the Royal Astronomical Society has been awarded to Dr. Isaac Roberts, F.R.S., for his photographs of star clusters and nebulæ. It is always a congenial task for the occupant of this chair to explain the reasons why the choice of the Council has fallen on any distinguished astronomer, and more especially so when it happens that it falls on one of our own Fellows. On both occasions on which I have occupied this chair the choice has so fallen. Last year my remarks were addressed to a consideration of the eye observations carried on for many long years by a single observer; this year the eye has to hold a subordinate place, giving way to the photographic plate as a recorder. The latter is a recorder in which there can be no systematic personal error as regards the relative positions of objects which cannot be discounted; and though photography in some particulars does not always speak the truth, yet for a study of the heavens its retina is capable of receiving more accurate impressions than that sensitive surface which lines the eye, and which transmits a message to the brain, more or less tainted with preconceived notions. Your retiring President is in a position to fully appreciate the magnitude of the work undertaken by Dr. Roberts. A thirty-two years' experience in every past or present photographic process has impressed deeply on his mind the remarkable strides that the science of photography has made since he first developed a wet plate. It seemed then to be amongst the improbabilities that a surface should ever be prepared which should be rendered so exquisitely sensitive to light that it could be with advantage employed by the astronomer who wished to make a register of the heavens. Most of the members of this Society who are photographers have only probably studied the "new photography," if it may so be called, which had its birth when Bennett showed that a salt of silver (the bromide) when suspended or emulsified in gelatine could have imparted to it, by long warming at a moderate temperature, a sensitiveness which was twenty to thirty times that of the same salt when

used in the ordinary wet process. The success thus achieved was not at the time fully appreciated, except by some few earnest workers, to whom the further improvement of the photographic plate naturally fell. The long heating at a gentle warmth took the place of the more brutal process of boiling the liquefied gelatine, and even heating was found to be unnecessary when strong liquid ammonia was added to it. Long were opinions divided as to the advantages of the hot over the cold preparation of the sensitive material, and I am inclined to believe that to the present day a diversity of opinion exists. But with improvements such as these a picture of a portion of the heavens, which Rutherfurd took eight minutes to obtain, can now be secured in a quarter as many seconds; and it is possible by very prolonged exposure to secure images of stars which have never been seen, though after their positions are known the eye is able to glimpse them in some of the largest telescopes.

The photographs by Common of the great nebula in *Orion* were epoch-marking in astronomical photography, and worthily was the medal bestowed on him for his classic work, and it is no disparagement of the labours of the present recipient if one traces in them the mark of what Common had shown to be possibilities. Dr. Roberts may have been said to have commenced his labours, which we are now considering, nearly ten years ago, for in 1885 April he had constructed for him by Grubb a 20-inch silver on glass reflector of nearly 100 inches focal length. As naturally to be expected when applying an instrument to a novel purpose, some defects in its mounting were found, and some short time elapsed before it was in such working order as to enable him to produce his first series of satisfactory negatives. This telescope, we are told, Dr. Roberts intended to use for charting the heavens on a scale twice that which Argelander adopted in the Durchmusterung; but when the International Congress was called together by Admiral Mouchez in 1887 he decided to devote it to another, though kindred, field of work, which also lay well within its capabilities; viz. the photography of star clusters and nebulæ. It is for the exploration of this field that the Council has awarded to Dr. Roberts the highest honour it can confer; and when we consider what such an exploration means, one will not doubt that this honour has been worthily and properly bestowed. The work was first carried on near Liverpool, but your Medallist became dissatisfied with the conditions which surrounded his observatory, and concluded that for a more rapid and satisfactory progress he must move to some place which gave better atmospheric conditions. Careful investigation showed him that the highest ground in the neighbourhood of Crowborough gave him what he required; and on Crowborough Hill he erected his observatory and remounted his telescopes, and from that time he has made his photographs there. Like Dr. Huggins he has a reflector and a refractor on the same mounting, the former being used

for photographic work, and the latter for visual observations: both are driven by one clock in Right Ascension, but they can be moved independently in Declination.

Speaking as a Fellow of the Society, and not as the mouthpiece of the Council, I cannot but congratulate Dr. Roberts on arriving at the conclusion that a reflector is better for his purpose than a refractor. The value of the identity of focus for all the spectrum components, and the possibility of having a ratio of aperture to focal length so large as 1 to 5, give the reflector an advantage which it is difficult to overrate. Star discs, when the reflector is properly figured, must be nearer theoretical perfection, and therefore are *not* exaggerated in size for large magnitudes. Dr. Roberts tells us, however, that the adjustment of a reflector is much more difficult than that of a refractor, and this may be well believed; but the extra trouble involved is well expended when one looks at the splendid results achieved, which are now placing him so prominently before the Society.

One of our Fellows and my immediate predecessor in this chair has perhaps unwittingly given the best proof of the excellence of the results by his measurements of the star discs taken with Dr. Roberts's reflector, and of those taken with refractors. He has shown that the images are much smaller with the former than with the latter, though the apertures employed in both cases are not such as to account for the difference from causes of diffraction.

In the report of the progress of the work carried on at the Crowborough Observatory, which has just been submitted you, occurs the following sentence which is worthy of special notice:—

"Some considerable portion of the autumn months was occupied in testing the new triple objective of 6-inch aperture, made by Messrs. T. Cooke & Sons. The lens proved to be *perfectly* 'achromatic,' no trace of secondary colour being visible around even the brightest objects. The visual and photographic foci were found, from a great number of careful experiments, to be exactly coincident, as in a reflector."

It may be that in an instrument such as this, the reflector will have a serious competitor in one respect for object-glasses of moderate sizes, but it may be doubted if it will ever be rivalled in the work which requires the utmost light-gathering power.

Turning to the absolute work that the Medallist has carried out, it should be stated that he commenced photographing the stars with various photographic lenses in 1883. The paper in which he recounted what he had done is found in the *Monthly Notices* of 1886 January. Each year since then he has contributed to the *Monthly Notices* papers on the subject of the research which he undertook, interspersed with others bearing upon stellar photography. In 1886 December he produced a photograph of the nebula in *Orion* with his 20-inch reflector, with an exposure of 15 minutes; and almost exactly two years

after he produced a photograph of the same object with an exposure of 81 minutes, and introduced us to nebulosities in the surrounding parts which were unsuspected before. Other photographs of the same object, with more prolonged exposure, can be also remembered. A little afterwards he produced his recently published photograph of the great nebula in *Andromeda*, giving an exposure of 4 hours to the plate. In this prolonged exposure we have an example of a triumph of patience, and of instrumental perfection, though these qualities are exhibited in other instances as well. This beautiful object is depicted with its rings of nebulosity in great perfection, and we can correct the eye observations which had previously been made on it. The stars in the field are beautifully sharp and round, showing that the eye as well as the instrument had to be employed throughout that long exposure to correct changes in position of the star due to atmospheric refraction, and variations in the rate of clock-driving.

About this photograph Dr. Roberts says: "This photograph will remain a permanent record, unquestionable in accuracy, of the state or the appearance of the three nebulæ (there are two others on the plate), shown on the night when the photograph was taken, so that any changes in the form or density of the nebulosity, or in the positions or magnitudes of the stars, will in future be capable of demonstration." In 1891, it may be remarked, he did actually discuss the photographic evidence of variability in the nucleus of his great nebula.

He adds: "These photographs throw a strong light on the probable truth of the Nebular Hypothesis, for they show what appears to be the progressive evolution of a gigantic stellar system."

How many stellar photographs he has taken it would be rash to endeavour to state, but some idea of their minimum number may be formed when it is stated that in the last three reports of the work done at the different observatories inserted in the annual Report of the Council, we find that at Crowborough, about 160 plates are recorded as having been successfully exposed. Nor can I venture to estimate the researches he has carried on as to the value of different brands of plates for his purpose. The astronomical photographer has to experiment largely on commercial wares before he begins his serious work. These experiments are not publicly recorded, and hence the labour involved can only be appreciated by those engaged in similar work. In Dr. Roberts's case the experiments were neither few nor far between. It is only by patient work of this kind that advances in our knowledge of the heavens can be obtained.

Last year our Medal was awarded to a gentleman who had wonderfully increased our knowledge of double stars by his laborious and unobtrusive work; and this year we are recognising the same kind of labour expended in bringing before us an acquaintance with those beginnings of systems which it was the privilege of but a few to scan imperfectly. Thanks to the skill which has made the 20-inch mirror, it is an obedient servant

instead of a tremulous slave, and its proper and systematized use has enabled the student of the universe at his leisure, and in the warmth of his study, to gaze at and scrutinize these ever-beautiful and mysterious objects, instead of seeking some one of them for some few hours on the finest of nights and in the cold midnight air. The solution of problems of the highest import in cosmical science is thus rendered far easier, and the thanks of all who interest themselves in such researches are due to those who, with such indomitable persistency, devote much of their time to pushing scientific discovery into those far-off regions of space.

I have not alluded to any other work which Dr. Roberts has carried out, though I might have mentioned his method of making direct engravings on plates from his negatives, a process which is certainly valuable and extremely ingenious. So far photography seems only to be limited by the physical features of the plate itself. Under the microscope the sensitive salt is a mass of small grains on which the image is received, and, as in the case of the cones in the retina, it is doubtful if a separation of two bright points is possible when they both fall on the same grain. The developed image is also a mass of small grains of probably very nearly pure metallic silver, and it may be doubted whether this also does not limit the application of photography in separating star discs very close to one another; but up to this limit, where grain becomes an important factor, it certainly has been used to the utmost by your Medallist. What the possibilities of the future may be, it would be somewhat rash to speculate. That something much more sensitive and much more homogeneous than the existing forms of silver salts as formed on a plate may be discovered seems a remote possibility. But, as I have pointed out elsewhere, the possibilities of a colour sensation being evolved must have seemed remote to our very early ancestors, who merely felt the sensations of light and form; and we must not take it as proved that nothing superior to a photograph, such as we know it now, may in the future be evolved. Be this as it may, Dr. Roberts's photographs, if they are preserved as they should be, will live to tell their own tale of what exists at the present time to students in centuries to come. That they will in our own days be rendered accessible as far as possible is proved by the issue, in June last, of that remarkable volume containing permanent prints of stars, star clusters, and nebulæ enlarged to a scale to show 24 seconds of arc to one millimetre, and in some cases but 6 seconds of arc. I cannot do better than quote the concluding paragraphs in its preface, which I had not read till I had penned my Address to this point.

"The photographs portray portions of the starry heavens in a form at all times available for study, and identically as they appear to an observer aided by a powerful telescope and clear sky for observing.

"Absent are the atmospheric tremors, the cold observatory,

the interrupting clouds, the straining of the eyes, the numbing of the limbs, the errors in recording observations, and the many hardships incurred by our predecessors, of glorious memory, in their attempts to see and fathom the ILLIMITABLE BEYOND.

"I commend the observations and the photographs herein to astronomers and students of the New Astronomy."

This last sentence your President re-echoes, and it gives him the greatest pleasure to hand to the Secretary for Dr. Roberts the Gold Medal of the Royal Astronomical Society, with the heartfelt wish that many more of our meetings may be enlivened by the beautiful pictures of the Heavens which he exhibits for our benefit, and which will be of inestimable value to those engaged in that branch of science which the Royal Astronomical Society was formed to foster.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :

President.

A. A. COMMON, Esq., LL.D., F.R.S.

Vice-Presidents.

Capt. W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S.
W. H. M. CHRISTIE, Esq., M.A., F.R.S., Astronomer Royal.
J. W. L. GLAISHER, Esq., M.A., Sc D., F.R.S.
E. J. STONE, Esq., M.A., F.R.S., Radcliffe Observer.

Treasurer.

E. B. KNOBEL, Esq.

Secretaries.

E. W. MAUNDER, Esq.
H. H. TURNER, Esq., M.A., B.Sc., Savilian Professor of Astronomy, Oxford.

Foreign Secretary.

WILLIAM HUGGINS, Esq., LL.D., D.C.L., F.R.S.

Council.

Sir R. S. BALL, M.A., LL.D., F.R.S., Lowndean Professor of Astronomy and Geometry, Cambridge.
G. H. DARWIN, Esq., M.A., LL.D., F.R.S., Plumian Professor of Astronomy, Cambridge.
A. M. W. DOWNING, Esq., M.A., D.Sc., Superintendent of the "Nautical Almanac."
RICHARD INWARDS, Esq.
FRANK MCCLEAN, Esq., M.A., LL.D.
W. H. MAW, Esq.
H. F. NEWALL, Esq., M.A.
Capt. WILLIAM NOBLE.
ISAAC ROBERTS, Esq., D.Sc., F.R.S.
G. M. SEABROKE, Esq.
Rev. WALTER SIDGREAVES, S.J.
E. J. SPITTA, Esq.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. MARCH 8, 1895. No. 5

Dr. A. A. COMMON, LL.D., F.R.S., President, in the Chair.

George Denton Hirst, Sydney, New South Wales, Australia ;
Samuel V. Hoffman, 1 Chelsea Square, New York City, U.S.A. ;
Henry T. C. Knox, F.R.G.S., Lieut. (late R.N.), 17 Upper Montague Street, W.;
E. F. J. Love, M.A., The University, Melbourne, Victoria, Australia ; and
The Rev. Daniel Higham Sparling, B.A., Rector of Biddulph Moor, Congleton,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :

Andrew Russell Forsyth, LL.D., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge (proposed by H. H. Turner) ;
John Willoughby Meares, Electrical Engineer, Clive Hall, Shrewsbury (proposed by Arthur Mee) ; and
William Willett, Junr., The Cedars, Chiselhurst Common, Kent, and 2 Sloane Gardens, S.W. (proposed by W. H. Thornthwaite).

One hundred and two presents were announced as having been received since the last meeting, including, amongst others :—

The Elements of the four inner planets and the fundamental Constants of Astronomy, by Simon Newcomb, presented by the

American Nautical Almanac Office; Annals of Harvard College Observatory, vol. xxxii., Part I. (Investigations in Astronomical Photography, by W. H. Pickering), presented by the Observatory; a sixteenth century celestial globe, on bronze tripod stand, presented by the Earl of Crawford; three large transparencies of portions of the Moon, from negatives made with the equatorial coudé of the Paris Observatory, presented by MM. Lœwy and Puiseux.

On the Rotation and Mechanical State of the Sun.

By R. A. Sampson, M.A.

(*Abstract.*) *

The author's aim is to consider with the simplest sufficient hypotheses the mathematical theory of the mechanical state and the relative motions of the parts of the Sun.

Starting from the equations of equilibrium of a gas, it appears that equilibrium is a state which will only exist either (1) when the temperature is maintained a function of the density, or (2) when all quantities are geometrically functions of only one parameter.

In the former case it is shown under what condition a body of gas will cohere in finite volume, and that if this condition is unfulfilled the density can nowhere be finite unless the total mass be infinite.

The study of the second case begins with the law of distribution of temperature. Conduction is assumed to be inoperative until instability producing convection currents is proved to exist, so that the agent of distribution must be taken to be radiation. The author shows that if three hypotheses be made—

(1) Each isolated small body of gas radiates heat at a rate proportional to its mass and to its absolute temperature conjointly.

(2) Each small body of gas absorbs heat proportionally to its mass, and to the quantity of heat that penetrates it, conjointly.

(3) The entire radiations from any element of a sheet of matter pursue the same course (normal to the wave fronts) without interference; then the temperature (θ) satisfies a partial differential equation, which yields the set of solutions—

$$\theta_n = a_n \exp\left(-\frac{2\varpi\mu_n^2}{\mu_n^2+\varpi'^2}\frac{t}{c}\right)\cos \mu_n m,$$

where μ_n is one of the roots of

$$\mu \tan \mu M = \varpi',$$

a is arbitrary, c, ϖ, ϖ' are certain constants, M is the total mass, and m is the mass within a certain surface passing through the

* For the complete paper, vide *Memoirs*, vol. li.

point considered. This applies to all arrangements in which the quantities are functions of but one parameter. Hence the temperature of a body cooling under radiation may be analysed into a number of elements, each of which cools at a definite rate; ultimately all others will disappear relatively to that of slowest rate.

Considering the equilibrium of a spherical body of gas under this law of temperature, it is shown that when the body is very great, the distribution of mass, density, and temperature is the following :—

r/a.	m/M	ρ/ρ_0.	θ/θ_0.
·0	·000	1·000	1·000
·1	·001	1·000	1·000
·2	·005	1·000	1·000
·3	·017	1·000	1·000
·4	·051	1·002	·997
·5	·079	1·008	·992
·6	·138	1·024	·977
·7	·223	1·064	·939
·8	·343	1·164	·858
·9	·520	1·461	·685
1·0	1·000	∞	0

Since the density increases outwards the distribution may be proved to be unstable, but the margin of instability being generally very small, the disturbances thence produced are not enough to change substantially the above distribution, except in the neighbourhood of the surface, where, if necessary, it may be supposed to give place to that of convective equilibrium.

If this theory be taken to apply to the Sun, we have a body affected throughout by convective currents, but substantially at uniform density and temperature, except near the surface, where this arrangement gives place to a rapid fall of temperature and density, accompanied by violent disturbance. This region of superficial violent disturbance appears as the main radiator, and it is shown numerically that this is a reasonable supposition. The main body, which is subject to less violent disturbances, radiates at a much lower rate, thence producing an effect of relative darkness.

Considering the rotation of the Sun, it appears that the data are not adequate to prove more than merely the sufficiency of an assigned cause. Starting from the equations of motion of a viscous gas, it is shown that Dunér's observations of daily angular rotation for 60° N. and S. lat. are consistent with the supposition of a velocity increasing inwards, and expressed by the formula

$$\omega = \omega_0 + r^{n-2}(\Omega - \omega_0),$$

where Ω is the observed surface rotation at any latitude, ω_0 is a constant derived from the calculations, and n is nearly equal to $2\frac{1}{2}$; taking $n=2\frac{1}{2}$, ω_0 is about one half the equatorial value of Ω. The data being indeterminative, the observations are also consistent with the above expression supplemented by an infinite arbitrary series; but it is shown that to attach a finite value to any term of this series implies that a finite part of the angular motion increases inwards at least as fast as r^{-2}, that is to say at much greater rate than the motion at the surface decreases towards the poles.

Finally it is shown that if the atmosphere follow the law of convective equilibrium, the associated surface motion in latitude is a slight drift towards the poles.

The Wilsonian Theory and the Stonyhurst Drawings of Sun Spots.
By the Rev. Walter Sidgreaves, S.J.

The question of the cavernous nature of a Sun spot has been recently brought prominently before the attention of Solar Physicists by the Rev. Mr. Howlett in a paper read at the last December meeting of the Royal Astronomical Society. His handsome present to the library of the Society is in evidence of the care and labour devoted to the subject, and the long series of large-size drawings contained in those eight volumes, covering a period of thirty-five years, seem to place his verdict against the Wilsonian theory beyond the reach of contradiction, and to show that it stands in no need of a confirming witness.

The Stonyhurst drawings extend over considerably less than half the years of Mr. Howlett's work, and are made to a scale, in diameter, only the one-third of his. They are therefore of much less weight, both in number and size. They were not commenced nor carried on with the direct object of testing the Wilsonian theory; but this was never lost sight of, and occasionally, when a spot was near the limb, a special drawing was made of it from an enlarged image, after the usual full surface drawing of $10\frac{1}{2}$ inches diameter was complete. The smaller drawing of the spot on such occasions was never retouched after its examination under the greater magnification; and the uniform agreement between the pairs confirms the rule that whatever is seen satisfactorily with less magnification is never contradicted by an enlarged image.

To form a safe estimate of the value of the smaller drawings for the subject of discussion, it should be remembered that in all cases the outlines of the umbra and penumbra were traced with a finely-pointed pencil over the image upon the paper, and that no drawing was considered complete until the draughtsman was satisfied that his picture faithfully represented what he saw. Hand-drawings made in this way have a value hardly inferior to

that of a photograph, and may be even more trustworthy when not more than one photograph has been obtained.

For the selection of suitable spots over 2000 drawings have been examined dating from 1881 to 1894, and only those which were found to satisfy recognised conditions of suitability have received a mark for or against the Wilsonian theory. These conditions are :—(1) That the spot had been observed at a position approximately between 30″ and 60″ of arc from either limb ; (2) that it had been watched on its passage between the central meridian and the limb ; (3) that it was a compact regular spot ; (4) that it showed a central umbra when remote from the limb : and (5) that it was a quiet spot, not indicating a tendency to divide or to change shape. We have 146 spots fulfilling these conditions. Of these 41 were double observations, the spots having been followed from limb to limb and observed near each. We have therefore 187 single tests, and of these 140 stand against, and 47 in favour of Wilson's doctrine, making a statement of 3 : 1 against it. But the individual cases are not of equal value, and when weighted on an estimate of 4 to 1 between the best and poorest of the selected spots the proportion rises to 3·66 : 1 against Wilson. This, so far, is a much weaker opposition than is established by Mr. Howlett's more valuable collection of drawings. But if we estimate the worth of the 47 cases quoted for Wilson on the lines of his own valuation of their testimony, nearly all the 47 witnesses will go out of court. Dr. Wilson, in "An answer to the objections stated by M. de la Lande,"* that the Wilsonian foreshortening was not always seen, points out that a shallow spot must be much nearer the limb than a deep and steep one to exhibit the same inequality of the two sides of the penumbra. and that a very shallow spot would go off the limb without showing any perceptible difference of this nature. To make this clear he gives computed angular distances, from the limb, of four cavernous depths, at which the more foreshortened side would contract to a line, and appends the corresponding apparent widths of the opposite side. His figures for spots of the first and second classes, in the order of decreasing depths, are :—at 60″ from the limb, the inward side of penumbra vanishing and outer side width 8″·58 ; at 30″ distance, inward side vanishing, outer side width 6″ 02.† Now of our 47 cases favourable to Wilson the best is perhaps the one near the eastern limb on 1886 May 21. It is a good spot with a good history, and judging by its size and darkness it should be ranked at least in Wilson's second class. It should therefore, when at 30″ from the limb, have lost the inward side of its penumbra : it was just within 30″ distance, and showed the

* *Phil. Trans.*, anno 1783, vol. lxxiii.

† The great spot of November 1769, which first drew Dr. Wilson's attention to the subject, was estimated, from his observations at the return of the spot in December, to have been at this limiting position, at 90″ from the eastern limb.

inward side a little more than half the width of the outer side. It may well be doubted whether Dr. Wilson would have formulated his cavernous theory upon these cases, which would indicate declivities too small to be worthy of notice. There is, however, one case which has no exception to its evidence, and which but for the smallness of the spot would take precedence of the one just mentioned. It crossed the Sun's disc in the last half of July 1884. It appears on the drawings at 35″ from the eastern limb on the 17th, and at 2′ on the 18th, quite clearly for Wilson. On the 19th the umbra was central at 3′ 30″ distance. On the 20th the umbra was broken on the eastern side ; but it had recovered on the 23rd, and remained quiet and central on the 24th and 25th. Finally, on the 28th, again at 35″ from the limb, it was the reversed picture of its first appearance. The diameter of the spot when near the middle of the disc on the 23rd was 20″, and it might be placed in Wilson's third class, which would not lose its inward penumbra at a distance greater than 15″.

In the course of looking through the drawings, for the purpose of this discussion, the necessity of care in selection has become very apparent. Many of the spots having full records of their behaviour in transit across the Sun's disc have been found untrustworthy witnesses, owing to the inconstant form of the umbra : the umbra may be spreading to one side, growing, or decaying, and the whole spot may be going through the process of division. A remarkable example of this kind of change is offered, as a warning, by a spot at about 20″ from the eastern limb on 1885 July 17. Its appearance then was very strongly in favour of Wilson's theory, and when near the central meridian on July 21 and 24 the umbra was quite sufficiently central to give any desired confirmation of the foreshortening effect at the limb. But on July 20, when the spot was at full 5′ from the limb, out of the reach of foreshortening, the penumbra was still dilated on the eastern side, and, comparing the drawings of the 21st and 20th, it was manifest that the umbra had extended eastwards to fill up the central void in the penumbra. If, therefore, this page of its history had been lost, the spot would have had great weight for the Wilsonian theory.

A similar example is the leading member of the twin spot on the drawings between 1888 May 11 and 23. This spot also went well for Wilson on the 12th, but failed afterwards. A new nucleus appeared on the 14th in the wider part of the penumbra, and the spot divided into a pair before arriving at the western limb.

Amongst the number of spots which tell against this supposed cavernous form there are not a few which go further and indicate rather a mountainous umbra, on the supposition of foreshortened effect upon the penumbra. The large round spot of 1887 June, selected by the late Father Perry to illustrate his paper in the *Memoirs* of the R.A.S. vol. xlix., is an instance of this. It was drawn on the 5th, when its centre was only 7″ of

arc from the eastern limb, and the picture shows no penumbra on the off side, or limb side, while it is well in sight on the inward side, as if a dark elevation were screening the further side of the penumbra from view. The spot was regular, and there was nothing in its history to favour the supposition that its eastern side was wanting in penumbra at the time. Another example merits attention on account of an enlarged drawing made of it, after the usual chart of the Sun's surface was finished. On both the smaller and larger pictures only a thin trace of the penumbra is seen on the limb side, while it is well in sight on the opposite side, the spot being only 7″ from the limb. These drawings were made on 1889 July 12, and show the beginning of the second rotation of the great spot of the year which lived from June 16 to August 20.

A strong confirmation of Mr. Howlett's conclusion is offered by a large number of the Stonyhurst drawings which show spots very near to either of the solar limbs. The argument is suggested by Wilson's reply to De la Lande already mentioned. He there extends his computations to fixing the narrower limits within which the nucleus must be "hid" by the "lip of the excavation." These limits for his four cases of decreasing depths are 16″·9, 8″·9, 4″·7, and 2″·7. We have probably between 400 and 500 drawings of spots of every size and intensity within 10″ of either limb. Of these about one third would probably have to be rejected as too small to give any certain evidence; and all the rest, if we may trust the memory of the observers, would show Wilson's nucleus, or, as it is now called, the umbra, quite distinctly. It has not been thought necessary to re-examine the whole series of drawings for this argument, but as a test of the accuracy of memory those of the years 1884 and 1889, periods respectively of maximum and minimum frequency, were selected, and these provided, together, 64 spots within the 10″ limit: 24 of these were useless, and the remaining 40, at distances from the limb from 2″ to 10″, showed the umbra well marked and quite distinct from the penumbra. It is therefore safe to conclude that the umbra is not often shut out of sight by the "lip of the excavation."

The notches, seen occasionally in the Sun's limb when a spot has been rounding it, are extreme evidences of this nature; and Wilson evidently felt the force of De la Lande's attack, founded upon these dark indentations reported by De la Hire in 1703 and by Cassini in 1719. His answer is founded upon the belief that these were at least very small—so small that his shallowest spots might show the nucleus when at zero-distance from the limb. He would have found it impossible to answer the Dehra Dun photograph of 1884 September 17.* This admits of no other explanation than that of a high elevation of the umbra. He

* A very faithful reproduction of this photograph is given in *Nature*, vol. xxxiii. p. 469.

might have rejected its evidence as proving too much ; and it must be admitted that if the photographic copy in our possession truly represents the border of the solar surface at the position of the spot, the phenomenon represented is of the rarest nature. We have nothing like it from the many observers of more recent times, including the hundreds of spots which must have beer observed by Mr. Howlett very near to the limb. If such a piling up of opaque matter were not rare in the extreme, it would have manifested itself by an East-to-West widening of the umbra at some of these many observed positions near the limb. There is no such widening shown on the drawings of this spot when it was approaching the western limb; the umbra had diminished in apparent East-to-West width by one half between the 15th and 16th of September, and should have contracted to a mere line on the 17th. The Stonyhurst drawing on the 17th was made at four o'clock in the afternoon, probably about ten hours after the Indian photograph, and may have been too late to catch the umbra on the limb ; only the penumbra is shown on the sketch. The Greenwich photograph was taken at $10^h\ 20^m$ A.M. of the same civil day—about four hours after the Indian photograph, and only the penumbra is quoted in the Greenwich volume as visible on the photograph. On the other hand, there is nothing on the Indian plate to indicate photographic treachery : the notching umbra is perfectly natural, of a strong silver deposit, and showing a woolly outline in every way like that of its neighbouring spot ; and although we have nothing to compare with it in our collection of drawings, there are imitations of it on a microscopical scale in the form of a little notch in the outer penumbra in spots near, but not on, the limb. These have been also observed by Mr. W. Hale White, who describes them in the *Journal* of the British Astronomical Association, vol. v., No. 4, as "constantly noticed. When a spot was close to the edge, the umbra rose in front of the outer penumbra like a projecting rock against the sky." It is impossible, therefore, to reject altogether the evidence of the Indian photograph, and it goes straight for a mountainous rather than a cavernous form. Mr. Howlett has already stated the inadmissible postulates required for a physically hollow notch : it would mean a deep furrow lying East-to-West, of so great a length that it could not have failed to manifest itself on the previous day.

Mr. Howlett has expressed a conviction that the penumbra of a spot "presents a convex surface—a curve conformable to the general contour of the solar orb" ; and, presumably, he includes the umbra in the curved surface. Our own observations at Stonyhurst, while confirming this statement as that of the usual form of a spot, lead to the admission of not unfrequent exceptions. It has been noted that some of the selected spots, which have been followed from limb to limb, score oppositely : at one limb for the Wilsonian doctrine, at another against it ; and, again, that, in several of the cases quoted against

Wilson, their opposition to his theory is more than contradictory of it: it is contrary to it, showing the wrong side of the penumbra contracted. Both these notes indicate elevation of the umbra rather than depression. It is a simple supposition, for bringing all the observations into accord, that the umbra, generally, is on a level with the penumbra, but sometimes above it, sometimes below. And it will probably be granted that this variation is more in keeping with the modern belief in some form of cloud-like opacity for the cause of the central darkness of a spot. The warmest supporter of the Wilsonion theory will hardly accept the physical part of it, that the darkness is the floor of a cavern opening to an opaque central mass; and without this prepossession on the part of Dr. Wilson it is not easy to see why he should have been at such pains to maintain that even shallow spots are but rare exceptions to a rule.

1895 *March* 3.

An Apparatus for Mechanically Calculating Star Corrections.

By W. E. Cooke.

(*Communicated by Professor H. H. Turner.*)

This machine, the principal part of which is shown in plan in the accompanying diagram (see plate 5), is mounted on a deal table with a cover, the top of which can be used as a drawing-board.

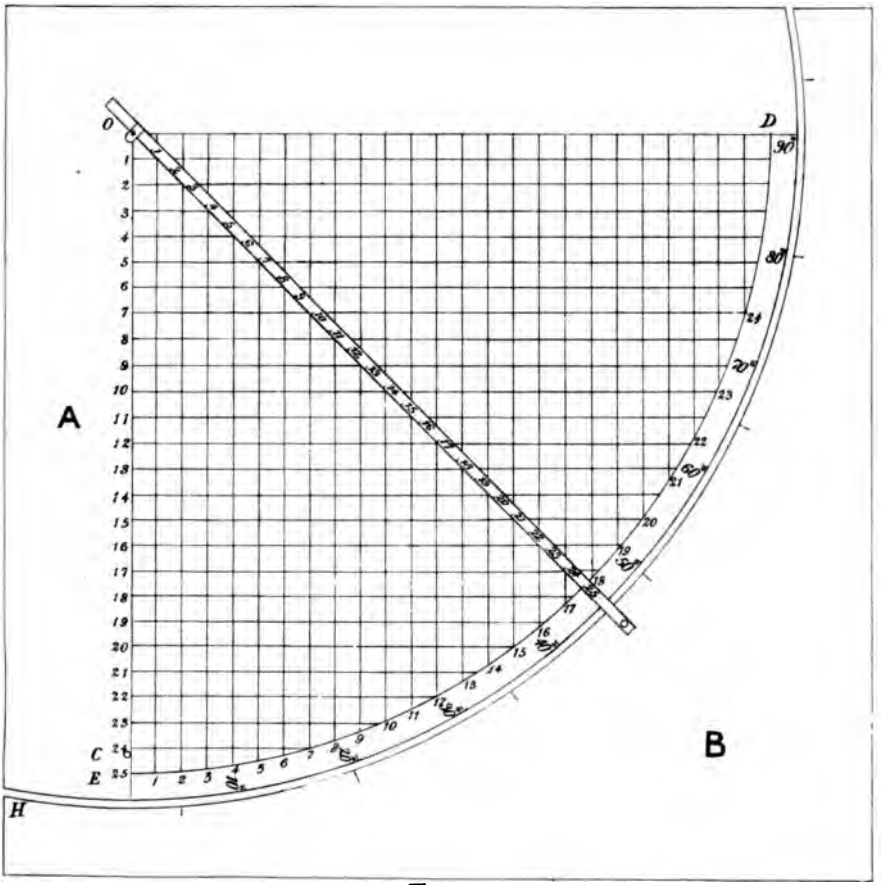
It consists essentially of a square sheet of zinc, divided into two portions, A and B, by means of a circular cut. B is fixed securely to the table top, and A is pivoted at O, a substantial spindle ($\frac{3}{8}$ inch thick) being screwed to the table, passing through a metal sheath in A, and projecting slightly above it. A flat metal straightedge, or ruler, 28 inches long, having a small metal projection near one end, through which a $\frac{3}{8}$-inch circular hole is drilled, with its centre exactly in line with the edge of the ruler, is pivoted on that portion of the spindle which projects above A. On the under side of A, at the point marked C, clamping and tangent screws are fixed, passing through a slotted aperture of 20° in the table top.

Thus both A and the ruler can be turned, independently of each other, on the spindle O, and A can be clamped in any desired position.

On A the quadrant ODE is drawn. Each line or radius OD and OE is divided into tenths of an inch, and perpendiculars drawn through each point, thus reticulating the quadrant into 0·1 inch squares. Every tenth division is marked by a thick black line, corresponding to each second of arc. (These only are shown in the accompanying diagram figured 0 to 25, commencing from the centre 0.) The half seconds, or every alternate fifth division, are drawn in red, and a thin black line marks the intermediate divisions, or tenths of seconds. The ruler, pivoted at 0, is similarly divided 0–25.

The edge of the quadrant is divided into degrees, and every tenth minute of arc, starting at E, and every minute can be easily estimated. The rim of B is graduated into hours and minutes, starting at H and extending for 7^h. The minutes are figured, but the hours are *not*.

For any given night's work we have a set of stars extending over 2 or 3 hours in R.A. Take any one of these hours, multiply by 15 to reduce to degrees, and add to G (from the *Nautical Almanac*). This gives $(G+a)$ corresponding to some whole hour of a. Let us take a simple case first. Suppose this value of $(G+a)$ is less than 90°. Turn A on its pivot until $(G+a)$ on the rim of A corresponds with some (unfigured) whole hour on the rim of B and then clamp. Then with a pencil figure this par-



Front.

ticular hour according to the above value of a. [As a matter of practice it is unnecessary to clamp, or to actually write in this value of a, for the stars to be reduced generally run straight forward in R.A.]

To obtain $g \sin (G+a)$ and $g \cos (G+a)$ for any value of a, move the ruler until its edge corresponds with the given value of a as read on B. The $\angle$ EOa will then be $(G+a)$, and the value of g on the ruler's edge will give $g \sin (G+a)$ and $g \cos (G+a)$ as read off on the reticulated quadrant. When these quantities have been obtained for each star, take out similarly the values of $h \sin (H+a)$ and $h \cos (H+a)$. Then set the ruler to the dec. of any star, and without moving it read off $[g \sin (G+a)] \sin \delta$, $i \cos \delta$, and $[h \cos (H+a)] \sin \delta$. Also, if it come within the limits of the machine, multiply the sum of $g \sin (G+a) \sin \delta$ and $h \sin (H+a)$ by sec. δ. This is done by reversing the above operation—*i.e.* take the value of this sum along OE and find where the corresponding perpendicular cuts the ruler. Of course, if either this sum, or the value of δ be large, the machine will not be able to multiply by the sec. δ.

We took just now the simple case where $(G+a)$ or $(H+a)$ is less than 90°. If it be $> 90°$, subtract either 90°, 180°, or 270°, as required, reading sin. for cos. where necessary, and prefixing the appropriate sign.

If, after setting A for some definite value of $(G+a)$ and running the ruler round the quadrant for successive stars, we reach D, we must bring the ruler back again to E, and read cos. for sin., and *vice versa*.

As to a practical test of accuracy and speed, we have only just completed the instrument at the Adelaide Observatory, and are not in a position to make a definite statement. But ten stars were taken, extending over about $1\frac{1}{2}^h$ R.A., and between $-12°$ and $+12°$ decl. These were reduced first by the machine, and secondly by Stone's tables. The greatest discordances were $0^s{\cdot}002$ in R.A., and $0''{\cdot}03$ in δ, and the machine reductions occupied only about half the time of the tabular.

I do not think the machine could be recommended for reducing in R.A. stars of high δ, unless the same error in arc be allowed for circumpolars as for stars near the equator, for the sum of two quantities $[h \sin (H+a)$ and $g \sin (G+a) \sin \delta]$ has to be multiplied by the sec. δ. It ought to reduce any star in NPD, no matter what its δ might be.

But I think the above difficulty might be overcome with a little tabulating and a modification of the reduction formulæ. Let us suppose two stars of the same R.A., but differing in δ. Call the decs. δ_1 and δ_2. Then the *difference* between the reductions in R.A. for those stars on the same date is

$$g \sin (G+a) (\tan \delta_1 - \tan \delta_2) + h \sin (H+a) (\sec \delta_1 - \sec \delta_2).$$

Suppose now that reductions were calculated for every tenth day for decs. 20°, 40°, and 60°, and tabulated for each hour of R.A. The reduction in R.A. for a star of, say, 68° δ would be effected as follows :—

First obtain reduction of a star of same R.A. and 60° δ by interpolation from tables. Then, with the machine, extract $g \sin (G+\alpha)$ and multiply this by $(\tan 68° - \tan 60°) = 0{\cdot}743$ = natural sine of 47° 59′. Similarly $h \sin (H+\alpha)$ (sec 68°-sec 60°) would be obtained, and the sum of these two quantities added to the reduction for 60° (obtained from the tables).

If this method be adopted, it will be advisable to figure the natural sines round the rim of A, and the only quantities required from the logarithm tables will be the tan δ and sec δ of each star.

Note on Mr. Cooke's Paper. By Professor H. H. Turner, M.A., B.Sc.

Just a year ago Mr. Cooke drew attention * to a method of simplifying the calculation of star-corrections in N.P.D., and I followed his paper by an account of some mechanical methods which I had been considering. An apparatus has since been constructed on the plan described in *Monthly Notices* liv. p. 367 by Messrs. Troughton and Simms, and used with success at the Royal Observatory, Greenwich.

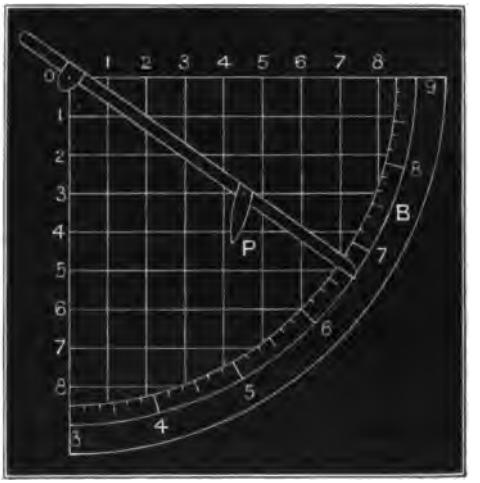
Mr. Cooke's present paper, which I received from Sir Charles Todd a few days ago, suggests one or two improvements in this plan, the importance of which I am glad to be the first to recognise. His use of the cross reticule instead of an extra sliding piece is an obvious convenience. But much more important is his remark that it is not necessary to figure the hours, but the minutes only. This reduces the necessary size of the machine to one quarter ; or, in other words, makes it possible to have a scale twice as large as before.

I may perhaps add, in my turn, to his suggestions as follows :—

(1) It is now not necessary to have two pivoted parts of the machine, as he suggests. The arc B may be clamped to the table if only we have a pointer P which may be attached to the revolving ruler in an arbitrary manner. Thus, suppose we wish to find $g \cos (G + \alpha)$, and that $G = 22^h\ 32^m$. Set the ruler to $0^h\ 28^m$, and make the point P fall on the zero line at the distance g. Then figure the hours 3, 4, &c., instead of 0^h, 1^h, &c. Hence

* *Month'y Notices* vol. liv. p. 358.

when the ruler reads $3^h\ 28^m$ on B, we get the pointer giving us g and o, which are the cosine and sine required.



(2) If any difficulty is found in having the zinc and paper reticule accurate enough, a glass reticule might be used, such as those employed for the Astrographic Chart. I am proceeding with the consideration of details on these lines.

A Systematic Comparison between the Places of Stars given in the Cape Catalogue for 1880 *and the Radcliffe Catalogue for* 1890. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

My wish is that the Radcliffe Catalogue for 1890 should be regarded as a continuation and completion of the general survey of the southern sky, which I commenced at the Cape in 1870. The agreement or disagreement of the results of these Catalogues is therefore, from my point of view, one of primary importance.

In collecting the materials for the Cape Catalogue, 1880, the chief object in view was to fix the positions of well-distributed zero points from the South Pole, N.P.D. 180°, to less than N.P.D. 115°, with all the accuracy attainable within the limits of the probable error of the mean of at least three observations of each element. In the collection of the materials included in the Radcliffe Catalogue the same plan has been followed for the stars from N.P.D. 115° to the Equator. But it was my earnest wish to render the results *as independent as possible* ; and to trust to the agreement or disagreement of the results which overlap as a test of the accuracy attained. I, therefore, purposely made the Oxford observations well overlap those at the Cape to afford materials for this comparison ; and I need hardly say that I have looked forward to the result with some natural anxiety.

The comparison has now been systematically and regularly carried out. The number of observations compared has been very considerable ; and the work of comparison has involved much arithmetical labour ; but the results can be exhibited in the form of tables, without taking up any great amount of space.

I have also added a comparison between the Radcliffe results and those of the Greenwich Ten-year Catalogue for 1880. The systematic differences are nearly the same as those between the Radcliffe Catalogue, 1890, and the Greenwich Five-year Catalogue of 258 Fundamental Stars for 1890, given in the *Monthly Notices* for November, 1894 ; but the comparisons given in the present paper include a much greater number of stars.

The positions in the Radcliffe Catalogue, 1890, for stars of much greater N.P.D. than 115° are not, of course, of much value, either in R.A. or N.P.D., except for discussion of questions of refraction ; and similar remarks apply to those of the Cape Catalogue for N.P.D. much less than 45°.

An examination of the differences in R.A. and N.P.D. between the Radcliffe and Cape Catalogues shows the existence of small but systematic differences both in R.A. and N.P.D. I am not, at present, able to give any perfectly satisfactory explanation of the cause of the change of these differences in R.A. with the N.P.D., which are certainly rather larger than I expected, and which possibly may be chiefly due to the Oxford observations,

although the R.A.'s of the Melbourne Catalogue, 1880, certainly show a similar law of discordance from those of the Greenwich Catalogue, 1880 (see Dr. Downing's Table V. p. 310, *Monthly Notices*, vol. li.). But these differences are at all events as small as those between the determinations of epoch corrections required by the different systems of fundamental stars at present employed; and the mean differences between the two Catalogues from the equator to N.P.D. 115° are so small that the results may be combined without leading to errors of any practical importance. The differences between the N.P.D. of the two Catalogues are so small that the application of a correction of + 0″·20 to the Radcliffe N.P.D. and − 0″·20 to the Cape N.P.D. would remove the discrepancy; and such errors are certainly within the limits of those which may arise from defects of the refraction tables in use.

The Greenwich observations differ more from the Radcliffe observations than those made at the Cape, and these differences agree with the results found from a comparison between the Greenwich, 1890, and the Radcliffe, 1890; but I have nothing, at present, to add on this point to my remarks in the *Monthly Notices* for November. With regard to the general accuracy of the Cape and Radcliffe results, I would appeal to the comparison between the Cape, 1880, and the Argentine General Catalogue for 1875 given by Dr. Downing in the *Monthly Notices* for June, 1887. As a matter of fact the N.P.D's of the Argentine Catalogue agree almost identically, in mean results, with the Radcliffe, 1890.

As a further check I give the comparisons between the results of the Cape Catalogue, 1885, lately published by Dr. Gill; but I have taken these results *directly from the General Catalogue, as found from the Cape work*, without applying certain corrections which Dr. Gill has shown would make his results agree rather more closely with those of the Greenwich Catalogues. This course is necessary if the agreement between the Cape and Greenwich results is to be appealed to as a proof of the accuracy of the positions of the stars given in these Catalogues.

The co-latitude of the Cape found by Dr. Gill from the circumpolar stars, and adopted in the formation of his Catalogue, is

$$123^\circ\ 56'\ 3''{\cdot}35;$$

whilst that adopted in the Cape Catalogue, 1880, is

$$123^\circ\ 56'\ 3''{\cdot}41;$$

and these results are, therefore, in close agreement.

The N.P.D.'s of the 1880 and 1885 Catalogues should therefore agree for stars at N.P.D. 124°. This is found to be the case; and the differences between the results should be confined within smaller limits than 0″·25 for all stars between N.P.D. 70°

and 124°, if they are unaffected by any other systematic errors than the effects on the refractions of a difference of 1°·6 F. due to an alteration of the thermometer exposures. But an examination of the differences of the division corrections applied 1870–1879 and 1880–1885, although small, will show that they are of the order of magnitude which is here under consideration. The results included in the Cape Catalogue, 1885, are also certainly not free from suspicion of systematic errors of sensible amount when the R – D discordance varies between +1″ and −1″ (see Table I. p. xvii. of the Cape, 1885, Catalogue); and although the R – D discordance was certainly confined within much smaller limits at the Cape, during the years 1874–1879, I am not prepared to assert that these observations may not have been affected by some small systematic errors due to the same causes which have affected the observations 1880–1885, and which I believe to be chiefly instrumental.

It should be mentioned that the fundamental epoch of the Cape Catalogue, 1880, is that of the Greenwich standard list; whilst Dr. Gill has adopted for the Cape Catalogue, 1885, the fundamental epoch of Dr. Auwers' "Fundamental-Catalog für die Zonen-Beobachtungen am nördlichen Himmel," and this is the chief cause of the small and nearly constant differences in R.A.

If the corrections, which Dr. Gill has deduced from a discussion of the Pulkowa and Greenwich observations, are applied to the results of the Cape Catalogue, 1885, the N.P.D.'s agree rather more closely with the Cape Catalogue, 1880, and less closely with the Radcliffe, 1890, than before; but the differences are in both cases *exceedingly small*, as will be seen on reference to the Tables given in this paper (see Tables I. and III.).

With regard to the non-application of any corrections for R – D discordance to the Radcliffe observations, the mean differences for R – D with the zenith-points found from the Nadir observations given in the results 1881–1887, after corrections for flexure have been, as they should be, applied, is for North stars −0″·235 with a weight 1518, and for South stars −0″·104 with a weight 2084, and these differences would only indicate an error in mean Nadir correction of

$$+0''\cdot080;$$

a quantity, whose effects are included in the co-latitude investigation, and which I consider too small and uncertain in its determination to render it necessary, for practical purposes, to discuss whether it is due to error of flexure correction, outstanding errors of division, or causes affecting solely the reflexion observations connected with atmospheric conditions in the observing room; or rather to their combined effects. My experience does not give me much confidence in the freedom of absolute places from systematic errors much less than ±0″·25; and, although I have tried to keep the errors as small as possible,

I certainly do not claim that either the results of the Cape Catalogue, 1880, or the Radcliffe Catalogue for 1890 are free from possible systematic errors within such limits. But the agreement between the Cape, 1880, results and those of the Radcliffe, 1890, is an unforced one; the systematic discordances are certainly confined within narrow limits; and the results of the two Catalogues combined afford positions of stars well distributed over the whole Southern hemisphere, which are not, so far as I can test them, affected with any serious systematic errors.

TABLE I.

Mean Results of Comparisons between Radcliffe, 1890, Stone, 1880, and Greenwich, 1880.

Group.	Mean N.P.D. of Group, Stone.	Differences in R.A. × sin N.P.D.				Differences in N.P.D.			
		Radcliffe minus Stone.	Wt.	Radcliffe minus Greenwich.	Wt.	Radcliffe minus Stone.	Wt.	Radcliffe minus Greenwich.	Wt.
°	° ′	s		s		″		″	
0–5	...	...	...	+ 0·014	636	...	...	−0·13	706
5–10	...	...	...	+0·024	17	...	...	+0·08	36
10–15	...	...	. .	−0·017	54	...	...	+0·11	88
15 20	...	...	...	−0·014	71	...	...	−0·23	157
20–25	...	...	...	−0·017	64	...	...	−0·40	160
25 30	...	...	...	−0 002	62	...	...	−0·68	194
30–38½	...	...	...	−0·005	55	...	...	−0·57	64
38¼–45	42 0	+0·015	4	+0·001	67	−0·72	10	−0·64	69
45–50	46 0	+0·030	5	+0·027	44	−0·27	7	−0 29	8
50–55	52 0	+0·045	11	+0·014	74	−0·83	13	−0·55	106
55–60	57 30	+0·042	22	+0·031	69	−0·10	6	−0·51	87
60–65	62 0	+0·056	118	+0 040	229	−0·33	24	−0·88	205
65–70	68 0	+0 041	130	+0·036	296	−0·60	36	−0·86	222
70–75	72 30	+0·057	151	+0·043	346	−0·39	29	−0·78	251
75–80	77 30	+0·037	233	+0·038	405	−0·48	45	−1·17	213
80–85	82 30	+0·034	293	+0·034	482	−0·36	69	−1·10	196
85–90	87 30	+0·036	181	+0·028	352	−0·53	48	−0·73	169
90–95	92 30	+0·017	397	+0 014	600	−0·49	193	−0·68	427
95–100	97 30	−0·004	352	−0·017	617	−0·63	179	−0·91	438
100–105	102 30	−0·021	259	−0·040	495	−0·38	174	−0·84	393
105–110	107 30	−0·024	277	−0·051	606	−0·47	123	−0·93	484
110–115	112 30	−0·053	642	−0·078	368	−0·36	550	−0·98	327
115–120	117 30	−0·064	303	−0 091	195	−0·04	254	−0·96	160
120–125½	122 30	−0·133	145	−0·158	45	+0 84	155	−0·79	47

TABLE

Differences between the Radcliffe Catalogue, 1890; the Cape Catalogue,

N.P.D. of Group.		0h to 6h. Radcliffe minus Cape, 1880.	Weight.	0h to 6h. Radcliffe minus Greenwich, 1880.	Weight.	6h to 12h. Radcliffe minus Cape, 1880.	Weight.	6h to 12h. Radcliffe minus Greenwich, 1880.	Weight.	*Differences of* 12h to Radcliffe minus Cape, 1880.	Weight.
°	°	s		s		s		s		s	
45 to	50	+0·036	1	+0·024	19	...	...	+0·006	8	...	...
50 „	55	−0·063	1	+0·025	32	...	...	...	...	+0·135	1
55 „	60	+0·025	3	+0·047	9	−0·025	5	+0·010	20	+0·061	10
60 „	65	+0·034	20	+0·029	44	+0·050	31	+0·064	44	+0·057	46
65 „	70	+0·067	37	+0·042	118	+0·028	87	+0·032	138	...	...
70 „	75	+0·042	44	+0·043	103	+0·052	58	+0·039	107	+0·076	47
75 „	80	+0·035	30	+0·047	70	+0·030	78	+0·039	124	+0·032	39
80 „	85	+0·023	75	+0·022	155	+0·029	94	+0·029	148	+0·050	33
85 „	90	+0·035	53	+0·025	84	+0·024	31	+0·028	79	+0·032	49
90 „	95	+0·005	136	+0·019	158	−0·003	76	+0·007	65	+0·035	101
95 „	100	−0·005	161	−0·010	197	−0·008	78	−0·019	73	−0·018	40
100 „	105	−0·036	73	−0·061	89	−0·025	63	−0·036	95	−0·002	48
105 „	110	−0·010	63	−0·053	82	−0·035	70	−0·053	98	−0·028	81
110 „	115	−0·055	173	−0·076	74	−0·066	132	−0·075	78	−0·057	185
115 „	120	−0·004	40	−0·012	6	−0·104	76	−0·114	38	−0·082	94
Means 45 „	120	−0·003		+0·005		−0·010		+0·003		−0·009	
„ 90 „	115	−0·021		−0·024		−0·031		−0·038		−0·022	
										Differences	
		″		″		″		″		″	
45 to	50	+1·03	4	+0·04	25	...	...	−0·72	8	...	...
50 „	55	+1·09	2	−0·32	19	...	...	...	...	−1·03	7
55 „	60	−0·03	2	−0·11	10	+0·05	2	−0·76	26	+0·27	1
60 „	65	−0·47	6	−0·71	43	−0·02	8	−0·92	27	−0·87	5
65 „	70	−0·50	14	−0·82	84	−0·81	19	−0·88	111	...	...
70 „	75	−0·39	10	−0·85	66	−0·45	9	−0·97	61	−0·34	9
75 „	80	−0·12	10	−0·96	40	−0·46	15	−1·27	76	−0·57	6
80 „	85	−0·38	26	−0·95	62	−0·13	16	−1·04	68	−0·68	5
85 „	90	−0·38	10	−0·58	31	−0·47	12	−0·75	49	−0·55	11
90 „	95	−0·46	87	−0·66	116	−0·50	54	−0·54	59	−0·66	22
95 „	100	−0·52	83	−0·85	119	−0·77	50	−0·71	64	−0·97	15
100 „	105	−0·17	51	−0·74	79	−0·41	49	−0·90	82	−0·82	14
105 „	110	−0·13	25	−0·88	61	−0·63	43	−0·65	86	−0·75	24
110 „	115	−0·45	163	−1·10	68	−0·36	111	−0·91	65	−0·23	133
115 „	120	−0·06	40	−1·45	6	+0·16	68	−0·57	39	−0·36	84
Means 45 „	120	−0·35		−0·78		−0·39		−0·85		−0·44	
„ 90 „	115	−0·41		−0·82		−0·49		−0·75		−0·43	

II.

1880; *and the Greenwich,* 1880; *for Six-hour Groups.*

R.A. sin N.P.D.

18h.		18h to 24h.				0h to 24h.				
Radcliffe minus Greenwich, 1880.	Weight.	Radcliffe minus Cape, 1880.	Weight.	Radcliffe minus Greenwich 1880.	Weight.	Radcliffe minus Cape, 1880.	Weight.	Radcliffe minus Greenwich, 1880.	Weight.	Mean N.P.D. in Cape, 1880.
s		s		s		s		s		° ′
+0·065	2	+0·054	4	+0·036	15	+0·050	5	+0·027	44	46·0
+0·005	19	+0·048	9	+0·009	23	+0·045	11	+0·014	74	52·0
+0·046	30	+0·093	4	+0·013	10	+0·042	22	+0·031	69	57·30
+0·035	96	+0·081	21	+0·037	45	+0·056	118	+0·040	229	62·0
+0·002	5	+0·067	6	+0·035	35	+0·041	130	+0·036	296	68·0
+0·045	123	+0·086	2	+0·052	13	+0·057	151	+0·043	346	72·30
+0·034	73	+0·047	86	+0·035	138	+0·037	233	+0·038	405	77·30
+0·064	38	+0·042	91	+0·045	141	+0·034	293	+0·034	482	82·30
+0·036	110	+0·046	48	+0·021	79	+0·036	181	+0·028	352	87·30
+0·013	179	+0·034	84	+0·013	198	+0·017	397	+0·014	600	92·30
−0·023	132	+0·008	73	−0·018	215	−0·004	352	−0·017	617	97·30
−0·033	144	−0·017	75	−0·037	167	−0·021	259	−0·040	495	102·30
−0·053	197	−0·019	63	−0·046	229	−0·024	277	−0·051	606	107·30
−0·086	130	−0·034	152	−0·071	86	−0·053	642	−0·078	368	112·30
−0·099	62	−0·038	93	−0·082	89	−0·064	303	−0·091	195	117·30
−0·006		+0·007		−0·010		−0·004		−0·002		
−0·035		−0·010		−0·027		−0·021		−0·030		

in N.P.D.

−1″·15	3	−1″·99	3	−0″·39	22	−0″·27	7	−0″·29	58	46·0
−0·79	39	−1·43	4	−0·43	48	−0·83	13	−0·55	106	52·0
−0·47	35	−0·92	1	−0·46	16	−0·10	6	−0·51	87	57·30
−1·03	83	−0·12	5	−0·77	52	−0·33	24	−0·88	205	62·0
−0·60	6	+0·27	3	−1·03	21	−0·60	36	−0·86	222	68·0
−0·67	117	−0·36	1	−0·27	7	−0·39	29	−0·78	251	72·30
−1·07	38	−0·72	14	−1·27	59	−0·48	45	−1·17	213	77·30
−1·64	17	−0·42	22	−1·19	49	−0·36	69	−1·10	196	82·30
−0·74	47	−0·64	15	−0·81	42	−0·53	48	−0·73	169	87·30
−0·70	137	−0·45	30	−0·76	115	−0·49	193	−0·68	427	92·30
−0·87	112	−0·55	31	−1·09	143	−0·63	179	−0·91	438	97·30
−0·79	95	−0·42	60	−0·90	137	−0·38	174	−0·84	393	102·30
−0·91	168	−0·31	31	−1·10	169	−0·47	123	−0·93	484	107·30
−0·85	113	−0·39	143	−1·11	81	−0·36	550	−0·98	327	112·30
−1·13	61	+0·20	62	−1·01	54	−0·04	254	−0·96	160	117·30
−0·85		−0·35		−0·95		−0·38		−0·86		
−0·83		−0·41		−1·00		−0·44		−0·87		

TABLE III.

Comparisons between the Cape Catalogues, 1880 (*Stone*), *and* 1885 (*Gill*).

Group. N.P.D.	Stone minus Gill in R.A. $\delta\alpha \cdot \sin\Delta$.	Weight.	Stone minus Gill in N.P.D. $\delta\Delta$.	Weight.
°	s		″	
70–75	−0·031	87	−0·13	23
75–80	−0·024	183	−0·08	47
80–85	−0·025	313	+0·04	94
85–90	−0·036	186	+0·23	56
90–95	−0·032	330	+0·29	142
95–100	−0·033	311	+0·27	136
100–105	−0·024	176	+0·28	111
105–110	−0·014	218	+0·35	104
110–115	−0·041	210	+0·29	123
115–120	−0·035	178	0·03	132

On the mean places of Eight Southern Close Polar Stars.

By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

In 1874 February I published and circulated the mean places of eight Southern close Polar Stars for the years 1860–1900. These places were deduced almost exclusively from observations made at the Cape Observatory, 1829–1873. The observations were brought up from one epoch to another, accurately by the trigonometrical method, with Peters' value of the precession constant; and the proper motions given are merely the small outstanding corrections found from a discussion of the residual errors, on the assumption that the places required corrections of the form

$$\text{constant} + \text{constant}\ (t - 1860).$$

The publication of a Cape Catalogue of 1,713 stars by Dr. Gill has led me to compare the computed places with the following Catalogues :—Cape, 1860; Melbourne, 1870; Cape, 1880; Cape, 1885; and the Appendix to the Cape, 1885, which gives the results of the circumpolar observations, 1881–1888 for the epoch 1885.

The agreement of the computed places with the catalogued places appears to me remarkable for such close circumpolar stars; in fact, the differences between the Right Ascensions given in the General Catalogue, 1885, and the Appendix are as great as the discordances between the computed and catalogued places themselves.

But my chief object in writing this Note has been to call attention to the smallness of the "proper motions in R.A." The fact that these residual motions are small for stars whose places were not employed in determining the precession constant, whilst the Right Ascensions of these eight stars change by such quantities as

$$-1^m\ 33^s;\ -28^m\ 30^s;\ +10^m\ 20^s;\ +16^m\ 11^s$$
$$+1^h\ 21^m\ 10^s;\ +1^h\ 25^m\ 55^s;\ +10^m\ 36^s;\ \text{and}\ +10^m\ 1^s$$

in 45 years, appears to afford independent evidence of the accuracy of Peters' value of the precession constant.

Name of Star and Adopted Proper Motions.	Year.	Mean R.A. Computed.	Observed.	Computed minus Observed $\delta\alpha \cdot \sin\Delta$.	Mean N.P.D. Computed.	Observed.	Computed minus Observed $\delta\Delta$.	Catalogue.
		h m s	s	s	° ′ ″	″	″	
o Octantis	1860	0 13 24·54	24·93	−0·006	179 8 29·18	29·15	+0·03	Cape, 1860.
+0ˢ·012	1870	0 13 5·43	4·90	+0·008	179 5 8·96	8·88	+0·08	Melbourne, 1870.
0″·00	1880	0 12 50·29	50·31	0·000	179 1 48·73	48·54	+0·19	Cape, 1880.
	1885	0 12 44·00	45·04	−0·018	179 0 8·63	8·20	+0·43	Cape, 1885.
	1885	0 12 44·00	44·82	−0·014	179 0 8·63	8·41	+0·22	Cape, 1885, Appendix I.
A Octantis	1860	8 20 17·14	17·23	−0·002	178 27 23·22	23·27	−0·05	Cape, 1860.
−0ˢ·014	1870	8 13 53·47	53·48	0·000	178 29 15·97	15·87	+0·10	Melbourne, 1870.
−0″·02	1880	8 7 13·28	12·64	+0·017	178 31 3·94	4·39	−0·45	Cape, 1880.
	1885	8 3 46·92	46·51	+0·011	178 31 56·06	56·31	−0·25	Cape, 1885.
	1885	8 3 46·92	46·17	+0·019	178 31 56·06	56·99	−0·93	Cape, 1885, Appendix I.
Brisbane 4091	1860	12 29 50·80	50·82	0·000	179 1 48·36	48·37	−0·01	Cape, 1860.
−0ˢ·088	1880	12 34 45·87	46·00	−0·002	179 8 25·50	25·32	+0·18	Cape, 1880.
0″·00	1885	12 36 10·64	11·96	−0·019	179 10 4·57	4·53	+0·04	Cape, 1885.
	1885	12 36 10·64	10·67	0·000	179 10 4·57	4·66	−0·09	Cape, 1885, Appendix I.
ε Octantis	1860	14 23 43·49	43·66	−0·007	177 33 54·68	54·65	+0·03	Cape, 1860.
−0ˢ·160	1870	14 27 20·95	20·83	+0·005	177 36 36·65	36·43	+0·22	Melbourne, 1870.
+0″·05	1880	14 31 6·17	5·56	+0·025	177 39 16·67	16·64	+0·03	Cape, 1880.
	1885	14 33 1·78	1·75	+0·001	177 40 35·92	35·83	+0·09	Cape, 1885.
	1885	14 33 1·78	0·79	+0·040	177 40 35·92	36·03	−0·11	Cape, 1885, Appendix I.

Name of Star and Adopted Proper Motions.	Year.	Mean R.A. Computed.	Observed.	Computed minus Observed $\delta\alpha \cdot \sin\Delta$.	Mean N.P.D. Computed.	Observed.	Computed minus Observed $\delta\Delta$.	Catalogue.
		h m s	s	s	° ′ ″	″	′	
σ Octantis	1860	17 48 8·80	7·89	+0·011	179 16 40·81	40·94	−0·13	Cape, 1860.
+0ˢ·075	1870	18 6 21·91	22·26	−0·004	179 16 43·40	43·33	+0·07	Melbourne, 1870.
+0″·02	1880	18 24 30·43	29·62	+0·010	179 16 30·02	29·92	+0·10	Cape, 1880.
	1885	18 33 28·93	30·42	−0·019	179 16 17·50	17·06	+0·44	Cape, 1885.
	1885	18 33 28·93	28·62	+0·004	179 16 17·50	16·90	+0·60	Cape, 1885, Appendix I.
B Octantis	1860	20 37 21·08	20·80	+0·003	179 28 51·78	51·96	−0·18	Cape, 1860.
−0ˢ·130	1870	20 55 36·26	36·71	−0·004	179 26 38·60	39·08	−0·48	Melbourne, 1870.
+0″·01	1880	21 11 31·45	31·72	−0·003	179 24 14·64	15·25	−0·61	Cape, 1880.
	1885	21 18 42·24	42·02	+0·002	179 22 59·27	60·17	−0·90	Cape, 1885.
	1885	21 18 42·24	44·15	−0·021	179 22 59·27	59·98	−0·71	Cape, 1885, Appendix I.
C Octantis	1860	22 3 34·62	34·82	−0·012	176 40 24·76	24·79	−0·03	Cape, 1860.
−0ˢ·035	1870	22 5 55·04	54·85	+0·011	176 37 28·18	28·18	0·00	Melbourne, 1870.
−0″·08	1880	22 8 11·88	12·00	−0·007	176 34 30·64	31·34	−0·70	Cape, 1880.
	1885	22 9 19·01	18·77	+0·014	176 33 1·53	2·38	−0·85	Cape, 1885.
	1885	22 9 19·01	18·74	+0·016	176 33 1·53	2·34	−0·81	Cape, 1885, Appendix I.
τ Octantis	1860	23 5 3·02	3·30	−0·009	178 14 55·70	55·73	−0·03	Cape, 1860.
+0ˢ·036	1870	23 7 14·37	14·12	+0·008	178 11 40·50	40·31	+0·19	Melbourne, 1870.
−0″·02	1880	23 9 18·98	19·18	−0·006	178 8 24·89	24·99	−0·10	Cape, 1880.
	1885	23 10 18·93	18·72	+0·007	178 6 46·95	47·33	−0·38	Cape, 1885.
	1885	23 10 18·93	18·84	+0·003	178 6 46·95	47·21	−0·26	Cape, 1885, Appendix I.

On the Proper Motion of the star B.A.C. 793.

By W. T. Lynn, B.A.

In the number of the *Monthly Notices* for May 1875 (vol. xxxv. p. 356) Professor Piazzi Smyth contributed a paper on the proper motion of the star *B.A.C.* 793 (=Piazzi II. 123), suggesting that this was variable in amount, and had sensibly diminished in R.A. and increased in N.P.D. Mr. Dunkin, however, showed from a discussion of the Greenwich observations that there was no real evidence of change of this kind in either element. He followed this up in the number for March 1876 (vol. xxxvi. p. 254), deducing the proper motion of the star from more recent Greenwich observations, which he determined to be $+0^{s}\cdot119$ in R.A. and $-1''\cdot50$ in N.P.D., and remarking that "the proper motion of *B.A.C.* 793 has not really changed during the present century." Mr. Stone also communicated a short paper after Mr. Dunkin's, pointing out that the Cape observations of the star in R.A. (none were available in N.P.D.) did not give any evidence of change in proper motion. The value used in the 9-year Catalogue (slightly modified in the 10-year) is the one determined by Mr. Dunkin, that in N.P.D. being about $0''\cdot2$ larger than the value given in the *B.A.C.*, which is $-1''\cdot31$, and had been adopted in previous Greenwich catalogues.

In a letter of mine which appeared in the number of the *Observatory* for last August, I showed, by comparing the places in the Greenwich 9-year and 10-year Catalogues, that there is some doubt whether after all the *B.A.C.* value of the proper motion in N.P.D. is not nearer the truth.

I will here set down the places derived from all the principal Greenwich catalogues, five of which contain observations of this star. They are as follows:

In R.A.

Catalogue.	Epoch.	h m s	No. of Obs.
12-year (first part)	1840	2 27 18·75	5
6-year (corrected)	1850	2 27 51·81	1
7-year	1860	2 28 24·47	29
9-year	1872	2 29 3·818	13
10-year	1880	2 29 30·084	13

The differences of these give for

	s		s
10 years	+33·06	annually	+3·306
10 years	+32·66	,,	+3·266
12 years	+39·348	,,	+3·279
8 years	+26·266	,,	+3·283

Now the mean annual precessions during these intervals are $+3^s\cdot158$, $+3^s\cdot159$, $+3^s\cdot160$, and $+3^s\cdot161$ respectively, deducting which, we find the resulting proper motion from each comparison $+0^s\cdot148$, $+0^s\cdot107$, $+0^s\cdot119$, and $+0^s\cdot122$, the mean of which is $+0^s\cdot124$. Or taking the difference from the extreme interval, 1840 to 1880, this is $+2^m\ 11^s\cdot334$ for forty years, or $+3^s\cdot283$ annually; thence deducting the mean precession, $+3^s\cdot160$, we obtain $+0^s\cdot123$ for proper motion, which would therefore appear to be a very accurate value.

In like manner:

Catalogue.	*In N.P.D.* Epoch.	N.P.D.	No. of Obs.
12-year (second part)	1845	83° 51′ 21″·82	5
6-year (corrected)	1850	83 49 56·99	1
7-year	1860	83 47 1·88	30
9-year	1872	83 43 31·02	14
10-year	1880	83 41 15·12	12

The differences of these, with the resulting annual changes, are:

5 years	−1′ 24″·83	annually	−16″·96
10 years	−2 55·11	,,	−17·51
12 years	−3 30·86	,,	−17·57
8 years	−2 17·90	,,	−17·24

The mean annual precessions during these intervals are $-16''\cdot02$, $-16''\cdot01$, $-15''\cdot98$, and $-15''\cdot95$ respectively, deducting which we find the resulting value of proper motion from each comparison $-0''\cdot94$, $-1''\cdot50$, $-1''\cdot59$, and $-1''\cdot29$ respectively, the mean of which is $-1''\cdot33$. Or, taking the difference from the extreme interval, 1845 to 1880, this amounts to $-10'\ 8''\cdot70$ for thirty-five years, or $-17''\cdot39$ annually; thence deducting the mean precession, $-15''\cdot99$, we obtain $-1''\cdot40$ for proper motion, of which, therefore, $-1''\cdot37$ would appear to be the most accurate value.

By the kind permission of the Astronomer Royal I am able to confirm and improve the above calculation by means of places derived from observations made at the Royal Observatory, Greenwich, in 1893 and 1894, but not yet published. These, reduced to the beginning of each year (none were made in 1891 or 1892), are as follows:

Year.	R.A. h m s	No. of Obs.	N.P.D.	No. of Obs.
1893	2 30 12·715	2	83° 37′ 26″·86	2
1894	2 30 16·028	5	83 37 9·35	5

Now a comparison of these places with those given in the 9-year Catalogue, the epoch of which is more than twenty years

anterior to their dates, leads to a proper motion of about $+0^{s}\cdot119$ in R.A. and $-1''\cdot43$ in N.P.D. It would seem, then, that the most probable value of the proper motion of this star is $+0^{s}\cdot121$ in R.A. and $-1''\cdot40$ in N.P.D. The latter value is about $0''\cdot1$ larger than that in the *B.A.C.*, and about $0''\cdot1$ smaller than that determined by Mr. Dunkin from earlier Greenwich observations. *Prima facie*, indeed, there is almost room for suspicion that the proper motion in N.P.D. is slowly increasing, though of course not in the way suggested by Professor Piazzi Smyth, which was founded on misconception.

Blackheath:
1895 *March* 4.

On the Proper Motion of the Star Cephei 24 (*Hev.*).

By W. T. Lynn, B.A.

In the Introduction to the eighth volume of the *Madras Observations*, which has been recently published, Mr. Michie Smith remarks that this star (which had been used for meridian error at Madras) had no proper motion assigned to it in the Greenwich 9-year Catalogue, but that there is little doubt that it has one considerable in amount. It is of the fifth magnitude, and is numbered 3402 in Groombridge's Catalogue, and Carrington considered that it had an appreciable proper motion. Mr. Stone follows the B.A.C. (where it is No. 7184) in locating it in *Ursa Minor*.

I have made an approximate determination of the proper motion, and herewith offer it to the Society, remarking that it can only be considered provisional, as the fractional proper motions have not been applied in the Catalogues, but it may form a basis for doing so in future. The star is included in both the Greenwich 7-year Catalogues, in the Greenwich 9-year, and in the last Radcliffe Catalogue for 1890. The places in each of these are as follows :—

Gr. 7-year Cat. 1860 ; R.A. $20^{h}\ 31^{m}\ 5^{s}\cdot49$ (5 obs.), precession $-43^{s}\cdot554$, sec. var. $-23^{s}\cdot6447$.

N.P.D. $1^{\circ}\ 17'\ 57''\cdot68$ (8 obs.), precession $-12''\cdot27$, sec. var. $+5''\cdot029$.

Gr. 7-year Cat. 1864 ; R.A. $20^{h}\ 28^{m}\ 10^{s}\cdot22$ (2 obs.), precession $-44^{s}\cdot483$, sec. var. $-24^{s}\cdot0088$.

N.P.D. $1^{\circ}\ 17'\ 7''\cdot94$ (4 obs.), precession $-12''08$, sec. var. $+5''\cdot184$.

Gr. 9-year Cat. 1872 ; R.A. $20^{h}\ 22^{m}\ 11^{s}\cdot693$ (4 obs.), precession $-46^{s}\cdot4169$, sec. var. $-24^{s}\cdot6431$.

N.P.D. 1° 15′ 32″·52 (4 obs.), precession − 11″·660, sec. var. + 5″·513.

Radcliffe Cat. 1890 ; R.A. 20h 7m 39s·885 (5 obs.), precession − 50s·9643, sec. var. − 25s·6826.

N.P.D. 1° 12′ 10″·57 (5 obs.), precession − 10″·603, sec. var. + 6″·313.

The interval between the epochs of the last two Catalogues is eighteen years, and the places are each founded in both elements upon not fewer than four observations. Reducing the Greenwich 9-year place to 1890 by precession only, allowing for its change, we obtain R.A. 20h 7m 35s·255, N.P.D. 1° 12′ 12″·16. And as the Radcliffe place for that year is R.A. 20h 7m 39s·885, N.P.D. 1° 12′ 10″·57, the resulting proper motion for eighteen years is + 4s·630 and − 1″·59, making its annual value + 0s·37 in R.A. and − 0″·09 in N.P.D. Comparison between the earlier Greenwich Catalogues essentially confirms this, only making the proper motion in R.A. a little larger (about + 0s·42), and also that in N.P.D. Comparison between the earliest Greenwich (7-year Cat. 1860) Catalogue in which the star is included and the Radcliffe, the interval between which is thirty years, gives a similar result, + 0s·405 in R.A. and − 0″·13 in N.P.D. ; so that there is no doubt the approximate value of this star's proper motion is + 0s·4 in R.A. and −0″·1 in N.P.D., exceeding that of Groombridge, 1830, in the former element.

I have been led to examine also the proper motion of the star 24 *Cephei*, i.e. that (Mag. 5-4) numbered 24 in Flamsteed's list of stars in that constellation, which is known to be very small. It is included in the Greenwich 6-year, the two Greenwich 7-year, the Greenwich 9-year, and the Radcliffe Catalogue for 1890. In the later Greenwich Catalogues the proper motion + 0s·003, + 0″·03 is adopted ; in the Radcliffe, + 0s·002, + 0″·007. A comparison of the places, however, in these would give one somewhat larger in N.P.D., whilst that in R.A. is clearly quite inappreciable. The places are as follows :

	R.A.	No. of Obs.	N.P.D.	No. of Obs.
	h m s		° ′ ″	
Greenwich 9-year	22 7 20·527	6	18 17 20·43	7
Radcliffe for 1890	22 7 41·387	6	18 12 2·95	7

The variations from these are in R.A. + 20s·860 for eighteen years, annual, + 1s·159 ; in N.P.D., − 5′ 17″·48 for eighteen years, annual, − 17″·64. And as the mean annual precession in the two elements is + 1s·1607 and − 17″·686 respectively, this comparison would give for proper motion − 0s·002 in R.A. and + 0″·05 in N.P.D.

Blackheath :
1895 *March* 1.

Observations of the Vertical Diameter of the Planet Jupiter.

By T. J. Moore, Field House, Hatfield, Doncaster.

(*Communicated by Dr. A. M. W. Downing.*)

Telescope used 5-inch reflector, power 125 and 50 diameters with Slade's micrometer.

1892.	No. of Observations.	Mean Value of one Night's Observations (vertical diameter).	Observed diameter reduced to dist. 5·20.	Obs. Vertical Diameter reduced to the Polar Value at dist. 5·20.	Error made on one night's observation, mean value =36″·11.
1892.					
Oct. 18	20	48″·03	36″·59	36″·16	+0″·05
25	40	47·93	36·75	36·32	+0·21
29	30	47·15	36·30	35·87	−0·24
Nov. 3	50	46·36	35·97	35·54	−0·57
10	40	45·95	36·14	35·71	−0·40
30	20	43·66	36·11	35·68	−0·43
Dec. 1	20	44·46	36·95	36·52	+0·41
2	10	44·07	36·75	36·33	+0·22
5	20	43·58	36·68	36·25	+0·14
6	20	43·08	36·38	35·95	−0·16
12	20	41·52	35·74	35·31	−0·81
13	10	41·67	36·00	35·57	−0·54
15	20	41·96	36·48	36·05	−0·06
1893.					
Nov. 22	20	47·93	37·17	36·99	+0·88
28	14	46·86	36·48	36·30	+0·19
Dec. 4	20	46·20	36·21	36·03	−0·08
5	5	46·38	36·39	36·21	+0·10
6	20	46·40	36·46	36·28	+0·17
7	20	46·58	36·66	36·48	+0·37
8	20	45·98	36·25	36·07	−0·04
9	20	45·38	35·83	35·65	−0·46
11	20	45·85	36·33	36·15	+0·04
12	20	45·92	36·41	36·23	+0·11
14	40	45·88	36·57	36·39	+0·28
15	20	45·77	36·55	36·37	+0·26
20	21	44·42	35·87	35·69	−0·42

1892.	No. of Observations.	Mean Value of one Night's Observations (vertical diameter).	Observed diameter reduced to dist. 5·20.	Obs. Vertical Diameter reduced to the Polar Value at dist 5·20.	Error made on one night's observation, mean value = 36″·11.
1893.		″	″	″	″
Dec. 22	40	44·54	36·14	35·96	−0·15
23	20	44·88	36·50	36·32	+0·21
1894.					
Dec. 22	20	45·26	36·19	36·16	+0·05
26	20	45·15	36·12	36·09	−0·02
27	12	45·34	36·30	36·27	+0·16
29	30	45·50	36·47	36·44	+0·33
1895.					
Jan. 2	20	45·30	36·42	36·39	+0·28
4	20	45·12	36·35	36·32	+0·21
5	20	45·11	36·38	36·35	+0·24
18	40	43·51	35·80	35·77	−0·34
21	20	43·92	36·56	36·53	+0·42
22	20	43·35	35·97	35·94	−0·17
23	20	43·67	36·32	36·29	+0·18
24	5	43·76	36·47	36·44	+0·33
25	3	43·56	36·39	36·36	+0·25
Feb. 11	10	41·08	35·90	35·87	−0·24
14	10	40·86	36·06	36·03	−0·08
23	10	40·07	36·37	36·34	+0·23
25	20	39·54	36·12	36·09	−0·02
27	20	38·94	35·80	35·77	−0·34
Total	960		Observations	=	36″·11

				Vert. Diam.	Correction.	Polar Diam.	Power.
From	320	obs.	1892	= 36″·37	−0″·43	= 35″·94	125
,,	320	,,	1893	= 36·39	−0·18	= 36·21	125
,,	320	,,	1894–5	= 36·22	−0·03	= 36·19	50
Total	960	,,	Mean Polar Value	...	...	= 36″·11 at dist.	5·20

In the reduction of these observations to the True Polar Value the compression of the polar axis is assumed to be $\frac{1}{16}$.

Results of Double-star Measures with the 8-inch Equatorial at Windsor, New South Wales, in 1894.
By John Tebbutt.

Ref. No.	Star.	Observed Magnitude	Approx. Place of Star. R. A.	Approx. Place of Star. Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour-angles.	Hour-angles.	Weight, 1 to 5.
			h m	° ′		°		″				h m	h m	
1	β Phœnicis	5, 5	1 1·4	47 17	·838	21·8	10	1·68	8	300	P	1 33 E	1 1 E	5
2	,,	5, 5	,,	,,	·841	22·5	10	1·80	10	300	P	3 25 E	2 58 E	5
3	,,	...	,,	,,	·846	23·2	10	...	...	300	P	3 19 E	2 59 E	3
4	,,	...	,,	,,	·849	24·9	10	1·45	10	300	P	3 18 E	2 51 E	5
5	ζ Phœnicis	4, 8	1 3·9	55 49	·890	243·2	10	...	...	230	P	1 35 E	1 1 E	2
6	,,	4, 8	,,	,,	·890	...	...	6·52	8	138	P			3
7	κ Toucani	5, 7	1 12·2	69 26	·846	354·9	10	5·50	10	300	P	2 49 E	2 18 E	4
8	,,	5½, 8	,,	,,	·849	354·9	10	5·49	10	300	R	2 47 E	2 18 E	4
9	,,	5, 8	,,	,,	·887	354·4	10	5·58	10	300	R	1 5 E	0 33 E	5
10	*h* 3447	...	1 31·2	30 27	·846	90·7	10	...	...	300	P	2 9 E	...	4
11	,,	5½, 8	,,	,,	·849	92·0	10	2·05	8	300	P	1 58 E	1 27 E	4
12	,,	6, 8½	,,	,,	·884	91·4	10	2·16	7	300	R	1 45 E	1 19 E	4
13	,,	6, 8½	,,	,,	·887	91·3	10	2·07	8	300	R	2 16 E	1 51 E	4
14	*p* Eridani	...	1 35·8	56 44	·772	...	...	7·59	10	170	R	5 4 E	4 47 E	4
15	,,	...	,,	,,	·772	...	...	7·37	10	170	P	1 54 E	1 34 E	5
16	,,	...	,,	,,	·775	...	...	7·26	10	170	R	4 32 E	4 14 E	4
17	,,	...	,,	,,	·775	222·9	7	...	...	300	P	3 53 E	3 21 E	3
18	,,	...	,,	,,	·780	225·3	20	6·99	10	300	P	3 55 E	3 13 E	4
19	,,	...	,,	,,	·789	224·4	10	7·34	10	300	P	...	3 21 E	5

Ref. No.	Star.	Observed Magnitude.	Approx. Place of Star. R. A.	Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour-angles.		Weight, 1 to 5.
			h m	° ′		°		″				h m	h m	
20	*p* Eridani	...	1 35·8	56 44	·805	225·0	10	7·39	10	300	P	2 11 E	1 37 E	5
21	,,	...	,,	,,	·808	225·4	10	7·41	10	300	R	3 22 E	2 51 E	5
22	,,	...	,,	,,	·813	226·2	10	...	...	300	R	3 58 E	3 30 E	3
23	,,	...	,,	,,	·816	224·8	10	7·41	10	300	P	2 38 E	2 8 E	4
24	,,	...	,,	,,	·819	224·5	10	...	...	300	P	3 47 E	3 28 E	3
25	,,	5½, 5½	,,	,,	·975	227·0	10	7·33	8	300	R	2 12 W	2 48 W	4
26	*h* 3592	6, 9	3 41·9	54 36	·838	17·0	10	5·28	10	138	P	3 20 E	2 36 E	5
27	,,	6, 9	,,	,,	·887	16·6	10	5·63	10	138	P	2 46 E	2 15 E	5
28	Lac. 2145	7, 7	6 2·0	48 27	·884	33·5	10	1·88	10	300	P	3 59 E	3 27 E	4
29	,,	7, 7	,,	,,	·967	31·8	10	1·60	8	300	P	2 51 E	2 24 E	5
30	,,	7, 7	,,	,,	·972	32·2	10	...	...	300	P	3 7 E	2 47 E	3
31	,,	7, 7	,,	,,	·975	31·2	10	1·52	10	300	P	3 4 E	2 32 E	3
32	α Centauri	...	14 32·4	60 24	·758	...	...	20·87	5	170	...	3 34 W	3 46 W	4
33	,,	...	,,	,,	·758	...	...	21·06	7	170	P	3 46 W	4 0 W	4
34	,,	...	,,	,,	·767	...	...	20·57	7	170	R	1 2 W	1 15 W	2
35	,,	...	,,	,,	·767	...	...	20·89	7	170	P	3 16 W	3 33 W	3
36	,,	...	,,	,,	·767	...	...	20·67	10	170	P	3 27 E	3 2 E	3
37	,,	...	,,	,,	·769	...	...	20·59	8	170	R	0 54 W	1 29 W	4
38	,,	...	,,	,,	·772	...	...	20·60	10	170	P	4 24 W	4 40 W	4
39	,,	...	,,	,,	·775	...	...	20·70	10	170	P	3 43 W	3 57 W	4
40	,,	...	,,	,,	·780	208·1	10	...	...	140	P	2 26 W	2 41 W	3

Ref. No.	Star.	Observed Magnitude.	Approx. Place of star. R. A.	Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour-angles.		Weight, 1 to 5.
			h m	° ′		°		″				h m	h m	
41	*a* Centauri	...	14 32·4	60 24	·780	208·1	10	...	...	300	P	3 30 W	3 42 W	4
42	,,	...	,,	,,	·789	208·7	10	20·69	10	140	R	1 34 W	2 6 W	4
43	,,	...	,,	,,	·789	207·3	10	20·74	10	300	P	3 9 W	3 34 W	3
44	,,	...	,,	,,	·789	208·4	10	...	...	300	R	3 39 W	3 49 W	3
45	,,	...	,,	,,	·789	208·4	10	...	...	300	P	3 49 W	4 0 W	3
46	,,	...	,,	,,	·802	207·3	10	20·59	10	300	P	4 28 W	5 3 W	4
47	,,	...	,,	,,	·805	208 0	10	...	...	300	P	4 6 W	4 20 W	3
48	,,	...	,,	,,	·805	208·2	10	...	...	300	R	4 47 W	4 57 W	4
49	,,	...	,,	,,	·808	208·1	10	...	...	300	P	2 55 W	3 10 W	4
50	,,	...	,,	,,	·808	208·1	10	...	...	300	R	3 12 W	3 22 W	4
51	γ Coronæ Aust.	...	18 59·3	37 13	·772	...	...	1·82	10	170	R	0 49 W	1 9 W	3
52	,,	...	,,	,,	·775	...	...	1·57	10	170	P	1 34 W	1 50 W	5
53	,,	...	,,	,,	·789	166·4	9	1·47	10	300	P	1 48 W	2 19 W	4
54	,,	...	,,	,,	·805	165·4	10	1·56	10	300	P	2 10 W	2 41 W	5
55	,,	...	,,	,,	·808	165·0	10	1·56	10	300	P	2 12 W	2 42 W	5
56	,,	$6\frac{1}{2}$, $6\frac{1}{2}$	,,	,,	·819	165·5	10	...	...	300	P	3 29 W	3 48 W	5
57	,,	...	,,	,,	·824	165·3	10	1·71	8	300	P	4 40 W	5 25 W	5
58	Lac. 8550	7, 7	20 42·8	62 49	·819	94·9	10	...	...	300	R	2 19 W	2 48 W	4
59	,,	...	,,	,,	·821	94·9	10	2·28	10	300	P	1 16 W	1 58 W	4
60	,,	...	,,	,,	·824	95·7	10	·88	10	300	R	2 5 W	2 43 W	5
61	h 5295$\frac{2}{3}$	6, $8\frac{1}{2}$	21 41·4	47 47	·895	359·8	...	44·31	5	74	P	2 35 W	3 11 W	4
62	,,	6, $8\frac{1}{2}$	,,	,,	·895	359·8	...	44·36	5	112	P			4

Ref. No.	Star.	Observed Magnitude.	Approx. Place of Star. R. A.	Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour-angles.		Weight, 1 to 5
			h m	° ′		°		″				h m	h m	
63	h 5295⅔	6, 8½	21 41·4	47 47	·904	359·8	...	44·44	10	74	P	3 0 W	3 28 W	4
64	„	6, 8	„	„	·967	359·8	...	44·50	7	74	P	3 7 W	4 4 W	4
65	„	6, 8½	„	„	·967	0·3	10	44·70	10	138	P	4 20 W	4 52 W	4

Remarks.

In the column headed "Eyes" P denotes that the line joining the observer's eyes was parallel to that joining the components, and R that these lines were at right angles. The column headed "Hour-angles" gives the hour-angles between which the measures were made, and that headed "Weight" gives the value of each result on a scale of 1 to 5, 1 denoting the worst possible, and 5 the best possible conditions.

With the exception of Nos. 14, 15, 16, 32, 33, 34, 35, 36, 37, 38, 39, 51, 52, 61, 62, 63, 64, the measures were made with the Cooke position filar micrometer. These measures were made with the Grubb filar micrometer without a position circle. No. 32 is the result of measured differences of declination with an assumed position angle = 208°.

For Nos. 14, 15, 16, 33, 34, 35, 36, 37, 38, 39, 51, 52, the transit thread was set parallel to the components, but for Nos. 61, 62, 63, 64 the distance threads were set parallel to the star's diurnal path. It was found during these four sets of measures that the components were together accurately bisected by the transit thread, so that the position angle is adopted as 359°·8, a small correction being applied for an error in the perpendicularity of the transit and distance threads. Nos. 32 to 50, both included, were observed in sunlight, and Nos. 2 and 3 in twilight.

The components of Nos. 1, 2, 4, 14, 15, 22, 23, 24, 25, 28, 29, 30, 51, 56, 58 were noted to be equal. Of Nos. 5 and 6 the primary was white and the companion pale blue.

The position angle of Nos. 10, 11, 12, 13 has increased about 15° since 1836. Hargrave, of Sydney, states that he could not divide the components in 1882 with a power of 333. As his position for the star is considerably in error, it is probable that he has mistaken another object for Herschel's star.

Of Nos. 26 and 27 the primary is straw yellow, and the companion bluish.

The south component of No. 31 was very slightly the brighter.

The position angle of Nos. 28, 29, 30, 31 has increased 50°, and the distance diminished 2″ since Herschel's observations in 1835. The position angle of Nos. 61, 62, 63, 64, 65 has diminished 14°, and the distance increased 14″ since 1836. The change is probably due to proper motion of the smaller star.

Windsor, N.S. Wales: 1895 *January* 15.

Corrections given on page 544

A List of Probably New Double Stars. By R. T. A. Innes.

During the last two months whilst I had the loan of a telescope belonging to Mr. W. F. Gale, of Sydney, I came across the double stars in the following list, all of which I believe are new. The telescope had a 6¼-inch object glass, made by T. Cooke, York, 1851, and was mounted on a rough equatorial without circles. The eyepiece used gave a power of about 360. I puzzled out the stars found, with the help of Proctor's smaller Atlas and Stone's Cape Catalogue, with fair success, but I generally add a note in reference to neighbouring stars, which will render the identification easier. The positions are for 1900. Angles, &c., are estimations. This list, the result of about thirty hours' searching, will prove what a mine of wealth awaits the diligent double-star observer in the southern hemisphere.

On account of the difficulty of identifying stars I confined my search to the neighbourhood of naked-eye stars, and only registered those which required some attention to notice their duplicity. None of these stars are in Herschel's or the Sydney Observatory lists.

G 1	Stone 1830	$4^h\ 14^m{\cdot}8$	$-61°\ 12'$
1894·8	300° ± 0″·8 ±	5½ and 7	2n

G 2	ξ Pavonis	$18^h\ 14^m{\cdot}0$	$-61°\ 32'$
1894·8	170° ± 4″·0 ±	5 and 10·7	2n.

Detected by Mr. Gale with his 8½-inch, previously to my seeing them.

A.A. 64 Toucanæ - (M.N. 59, 541)

No. 1	λ¹ Toucanæ	$0^h\ 49^m{\cdot}4$	$-63°\ 25'$
1894·9	90° ± 3″ ±	6 and 8·5	1n.

This star is marked double in Proctor's smaller Atlas, whilst λ^2 *Toucanæ*, a double discovered by Dunlop, is not so marked. Professor Auwers in his proposed list of southern standard stars also overlooked the duplicity of λ^2.

No. 2	St. 1746	$4^h\ 1^m{\cdot}1$	$-59°\ 51'$
1894·9	90° ± 2″ ±	7·5 and 9	1n.

The S star of a small finder pair making a right angle with ε and ι Reticuli :

No. 3	St. 2879	$6^h\ 11^m{\cdot}5$	$-61°\ 27'$
1894·8	350° ± 0″·8 ±	6·5 and 7	2n.

No. 4	St. 3041	$6^h\ 27^m{\cdot}4$	$-40°\ 22'$
1894·9	340° ± 1″ ±	6 and 6·1	2n.

The leading star of an oblong of six as seen through the finder.

No. 5	St. 3148	$6^h\ 36^m{\cdot}9$	$-61°\ 27'$
1894·9	270° ± 1″·7 ±	6·5 and 8·5	2n.
No. 6	St. 3213	$6^h\ 43^m{\cdot}5$	$-61°\ 7'$
1894·9	230° ± 1″·1 ±	7·8 and 7·8	2n.
No. 7	St. 3567	$7^h\ 14^m{\cdot}6$	$-46°\ 49'$
1894·9	220° ± 1″·5 ±	7 and 9·5	1n.

Both orange. The fourth star of five in a sickle—

No. 8	St. 4085	$7^h\ 59^m{\cdot}2$	$-44°\ 23'$
1894·9	320° ± 4″ ±	6 and 10	1n.
No. 9	St. 4287?	$8^h\ 15^m{\cdot}9$	$-73°\ 30'$
1894·8	280° ± 0″·9 ±	6 and 7	1n.

An eleventh mag. star 1′ N *f*.

No. 10	δ Argûs	$8^h\ 41^m{\cdot}9$	$-54°\ 20'$
1894·9	180° ± 3″ ±	2·5 and 5	2n.

As this star is much more difficult than *Antares* (2″·8), the distance is probably overestimated. Herschel noted a faint companion 80″ away.

No. 11	St. 4939	$9^h\ 11^m{\cdot}6$	$-45°\ 8'$
1894·9	270° ± 1″ ±	6·5 and 7	1n.
No. 12	St. 5008	$9^h\ 17^m{\cdot}6$	$-74°\ 28'$
1894·8	290° ± elongated	5 and 6	1n
1894·9	Round, good seeing		1n.

This is the chief star of the triple *h* 4206.

No. 13	St. 5534	$10^h\ 7^m{\cdot}0$	$-68°\ 11'$
1894·9	340° ± 1″ ±	7 and 7	1n.

Both white. This is the brightest of the stars near *ω Argus*, and is N from it.

No. 14	Anon.	$12^h\ 6^m \pm$	$-51°\ 35' \pm$	
1894·9	$140° \pm$	$3'' \pm$	7 and 9·5	In.

Not in Stone's Catalogue. Just N of ρ *Centauri*.

No. 15	St. 8844	$16^h\ 10^m·7$	$-64°\ 24'$	
1894·8	$300° \pm$	$0''·8 \pm$	7 and 9	2n.

R 275, a coarse ninth mag. pair is about 5′ N *p*.

No. 16	St. 2674	$5^h\ 49^m·5$	$-38°\ 33'$	
1894·9	$110° \pm$	$1'' \pm$	6 and 10	large star, orange, In.

[The brightest star in finder S of η *Pavonis*.]

No. 17	St. 11035	$20^h\ 37^m·8$	$-50°\ 51'$	
1894·8	$210° \pm$	$1'' \pm$	$7\frac{1}{2}$ and $7\frac{1}{2}$	2n.

This makes a small triangle with some other 7 mag. stars near ι and η Indi. It is a coarse double 7 and 7, 90° ± 100″ ±, and the preceding star is the close double.

No. 18	~~St. 11109~~ Lec. 8602	$20^h\ 48^m·0$	$-53°\ 58'$	
1894·8	$0° \pm$	$5'' \pm$	7 and $11\frac{1}{2}$	2n.

The chief star is red. If a line is drawn from α Indi through η Indi, two stars will be found on it. [S of η Indi, this is the second star.]

No. 19	Anon.	$21^h\ 41^m \pm$	$66°\ 10' \pm$	
1894·9	A and B	$350° \pm$	$0''·8 \pm$	7·8 and 10 In
	A and C	$290° \pm$	$10'' \pm$	12 In.

Very delicate ; about 1° S. of St. 11489.

No. 20	St. 11660	$22^h\ 9^m·3$	$-63°\ 50'$	
1894·9	$320°$	$0''·6$	6·5 and 7	In.

Midway on a line joining α and δ *Toucani* will be found St. 11673 : this star is N *p*.

No. 21	St. 11835	$22^h\ 36^m·6$	$-47°\ 43'$	
1894·9	$140° \pm$	$5'' \pm$	6 and 11·5	In.

Chief star orange. This and *h* 5362, a star of the same style, but easier, are both near β *Gruis*.

No. 22	τ^2 Gruis	$22^h\ 49^m·5$	$-49°\ 0'$	
1894·9	$200° \pm$	$0''·6 \pm$	6·5 and 8·0	3n.

Only elongated, but quite certain. τ^2 *Gruis* is 90″ N. of St. 11933.

No. 23	St. 12156	$23^h\ 22^m{\cdot}6$	$-56°\ 59'$
1894·9	$320° \pm 1'' \pm$	8 and 10	2n.
No. 24	St. 12192	$23^h\ 27^m{\cdot}9$	$-57°\ 35'$
1894·8	$220° \pm 2'' \pm$	6·5 and 9	3n.

This star is 90″ N. of another 6·5 mag. star.

No. 25	Anon.	$23^h\ 29^m \pm$	$-58°\ 14' \pm$
1894·9	$50° \pm 1'' \pm$	7·8 and 7·8	1n.

Near St. 12192 ; in the telescope field this is the preceding star of an elongated cross.

No. 26	St. 4019 ..	$7^h\ 54^m{\cdot}4$	$-47°\ 37'$
1894·9	$10° \pm \frac{21}{74}''$	6 and 7	One third of the way

from R Puppis towards γ Argûs.

Sydney, N.S.W.:
1894 *December* 10.

Note from author dated 1895 *January* 25.—"I find that No. 2 was measured by Mr. Sellors in 1891 (see *Ast. Nach.* No. 3154) ; also that Nos. 21 and 24 were observed on the meridian some years ago at Cordoba, and the *Comes* noted at the same time. Consequently these three stars are not new."

The Transit of Mercury, 1894 *November* 10. By Walter F. Gale.

The transit of *Mercury*, so far as it was visible in New South Wales, was well seen by eight observers in Sydney.

At the time of egress definition was noted by me as very good. My internal contact was probably early, but the more difficult external contact was recorded as exceptionally satisfactory. The following times were registered by counting the beats of the sidereal chronometer, which was previously and subsequently verified :

	h	m	s	
Internal contact at egress, Nov. 10 ...	9	11	30·8	G.M.T.
External „ „ „ ...	9	13	23	„

My position is $10^h\ 4^m\ 54^s{\cdot}79$ E. $-33°\ 53'\ 12''{\cdot}3$.

Mercury appeared as an intensely black circular object, without fringe or detail of any kind. The umbra of a Sun-

spot, near which the planet passed, was decidedly less black than *Mercury*.

The instrument used was the 8½-inch equatorial reflector, aperture reduced to 5 inches and provided with a Sun diagonal and achromatic eyepiece magnifying 96 diameters.

Paddington, Sydney, N.S.W.:
1894 *November* 14.

The Transit of Mercury, 1894 *November* 11; *Egress*. By J. P. Thomson, F.R.S.G.S., &c., President of the Royal Geographical Society of Australasia, Brisbane.

(*Communicated by the Secretaries.*)

The instrument used to observe the transit of *Mercury* was an equatorially mounted refracting telescope, 6 feet focal length, with object-glass 6 inches in diameter, built by Sir Howard Grubb in 1884. It is the property of Mr. F. D. G. Stanley, F.R.I.B.A. The telescope rests on a hollow cast-iron column, 5 feet 9 inches in height, and 18 inches diameter at the base, in which is placed the driving clock. The whole metal work is mounted on a stone and concrete foundation carried down to the solid rock 6 feet below the surface of the ground, perfect freedom from vibration being thereby secured.

The observatory, which is situated at "Ardincraig," Toowong, the private residence of Mr. Stanley, is a wooden building, 12 feet square, with roof arranged so as to roll entirely off on a railway and framing built to receive it. There can be no doubt whatever that, in a fine climate, this arrangement possesses many advantages to which I shall refer later on. Included in the equipment of the observatory is a transit instrument, by Carl Bamberg, of Berlin (1879). This is placed upon a stone pedestal. The observations are taken through the hollow central axis of the instrument, the eyepiece being fitted with micrometer. A magnifying power of 100 diameters was used in the equatorial for the actual observation of the transit, this having been found, after repeated tests, to give the most perfect definition. The object-glass of the telescope was stopped down to 3 inches.

The party consisted of his Excellency General Sir Henry Wylie Norman, Governor of Queensland, Messrs. F. D. G. Stanley, and Arthur Cleminson, of the Surveyor-General's Staff, time recorders, and myself, who observed the transit. There were three chronometers used, namely:—No. 542, mean time, by Frodsham, in charge of his Excellency the Governor; No. 2139, also mean time, by Arnold, in the hands of Mr. Stanley, and No. 4230, sidereal, by Kullberg, under the care of Mr. Cleminson. The first belongs to Mr. Stanley's observatory, but the others, one of which is the property of the Hon. A. C. Gregory, were

duly compared with the standard clock at the Brisbane City observatory for several days previous, and late on Saturday night, immediately before Mr. Cleminson and I transported them to Toowong, the former gentleman finally checked them by meridian stars. After the transit had been observed the chronometers were at once returned to the City observatory and recompared. No. 4230 was found to have undergone no change whatever in transit, but there was a very slight displacement observed in the rate of the mean time chronometer. This recalls to my mind a similar experience at the time I was preparing to observe the transit of *Venus* at Levuka, Fiji, in 1882. On that occasion three chronometers were also rated, although only one, the best, was actually used to record the times of the observations. Some two weeks before the date of the transit they were transported with the greatest possible care for a very short distance from the Harbour Master's Office to the observatory, when it was found that a very slight change of rate had taken place.*

Weather.—Shortly after 5 o'clock the sun rose above a clear horizon free from the slightest trace of haze. The whole sky was cloudless, the weather nearly a dead calm, and the atmosphere almost phenomenally steady and agreeably warm. A few preceding days of fine clear dry weather had happily dissipated the moisture accumulated in the atmosphere during previous daily showers, and thus we were privileged to conduct the observations under the most favourable conditions, in every respect typical. After considerable experience in astronomical work, I can honestly state that in no climate have I ever conducted astronomical observations under more favourable atmospheric conditions than those prevailing at Brisbane on the morning of 1894 November 11. A fair idea of these may be conveyed by stating that from sunrise till shortly before the internal contact the planet appeared against the solar surface as a clear and sharply defined disc through a small portable telescope which Mr. Stanley had placed outside the observatory door, and Mr. C. B. Lethem, observing with a 5-inch theodolite at Clayfield, some six miles north-east of our position, was able to record the interval of time between internal and external contacts by an ordinary watch to within 17 seconds of the calculated interval. I have purposely emphasised this description of the weather, having long ago arrived at the conclusion that the so-called black drop and other somewhat remarkable phenomena associated with the observations of the transit of planets are due to terrestrial causes, and not celestial. In other words, they arise from unfavourable atmospheric conditions, from telescopic defect, or from some peculiarity in the physical condition of observers, either one or all combined. This subject has, I may state, been very ably elucidated by the distinguished astronomer Mr. H. C. Russell in

* *Proceedings and Transactions of the Royal Geographical Society of Australasia. Queensland*, vol. vii. p. 93.

a valuable paper upon the previous transit of *Mercury*, contributed to the Royal Society of New South Wales, 1881 December 7. My own experience entirely confirms the views advanced by Mr. Russell.

The Observations.—At 5 hours 10 minutes the equatorial was pointed to the Sun. The several small clusters of spots which had been observed on the solar surface for some few days previous were clearly visible as the Sun gradually cleared the neighbourhood of the horizon. There was no difficulty whatever in distinguishing the planet, for *Mercury* at once appeared in the field as a most perfect sphere, intensely black, with remarkably clear and sharply defined periphery. For some time I sat intently watching this interesting object as it slowly moved across the great solar surface. Particular attention was given to an examination of the effect of different magnifying powers and of various intensities of light by a manipulation of the combination of dark glasses used in the eyepiece of the telescope, but this produced no change whatever in the appearance of the planet. The definition was perfect, and there was not the slightest trace of haze, band of light, or vaporous aureola around the disc of *Mercury*. Attention was next bestowed upon a very minute white spot that appeared upon the surface of the planet. I was aware that a similar object had been noticed by several observers during previous transits, although I had failed to see anything of the kind at the transit of 1881, which I observed with a small telescope under distressing conditions. In this instance the steady, unchangeable appearance of the object left no doubt in my mind whatever that it was something more tangible than an optical illusion. I removed the lower magnifying power, and applied one of 450 diameters, and at first thought I saw two white spots close together, but after the eye had accommodated itself to the change the second spot assumed a very uncertain appearance, and for this reason I doubt its existence altogether; the first, however, remained unchanged. When about to observe internal contact, I was somewhat startled by what appeared, for the moment, to be a slight indication of ligament, but the phenomenon was only momentary, and I regard it as purely optical. When external contact occurred the limb of the Sun and that of the planet were remarkably clear, sharp, and well defined. There was not the slightest trace of disturbance in the limbs of the two bodies, and I have every confidence in recording the phase as a pure geometrical contact.

I very carefully watched for the planet when it separated from the Sun, but no trace of its periphery could be distinguished from the dark space beyond.

Taking the mean of the three chronometer records, the following are the corrected times of the observations, namely—

	h	m	s
Internal contact	7	23	42·45
Geometrical external contact ...	7	25	28·00

The above are the mean times at Brisbane Observatory in latitude 27° 29′ 0″·2 S., and longitude $10^h\ 12^m\ 0^s$ E. We occupied a position of about 6534 feet south and 10,428 west of the Brisbane Observatory.

Regarding Mr. Stanley's observatory it will probably be found in general practice that a telescope is capable of doing better work when placed within a building with the roof entirely off than in one enclosed by the common revolving circular dome. In the former the air currents are more likely to be nearly uniform in temperature, while in the latter type, opposing currents of air of unequal temperature are apt to materially influence definition. It is not, I believe, an extremely high nor abnormally low temperature an observer need fear, but unsteady and constantly changing air currents, within the observatory as well as without, that are inimical to good telescopic work. Once modify or minimise these conflicting elements, maintain uniformity of temperature in the observatory, and the results of astronomical observations will probably rise 50 per cent. nearer the truth than at present.

In conclusion I have great pleasure in acknowledging the efficient aid rendered by the three gentlemen with whom I was associated in this work, and of testifying to the satisfactory degree of accuracy of the times recorded by them.

Observations of Encke's Comet made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East, or Sheepshanks, Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time.				Observer.	☄−✱ RA.	Corr. for Refraction.	Corr. for Parallax.	☄−✱ N.P.D.	Corr. for Refraction.	Corr. for Parallax.	No. of Comps.	Apparent R.A. of ☄.	Apparent N.P.D. of ☄.	Comp. ✱
1895.	d	h m	s		m s	s	s	′ ″	″	″		h m s	° ′ ″	
Jan.	13	5 33	2	B.	−2 10·14	−0·03	+0·35	+12 50·9	+0·4	− 9·4	2	22 5 12·93	89 32 44·9	*a*
	13	5 43	29	,,	−3 15·03	+0·01	+0·37	− 5 31·3	−0·2	− 9·4	4	22 5 12·43	89 32 54·7	*b*
	14	6 12	21	H. F.	+3 33·65	0·00	+0·42	+ 1 25·7	+0·1	− 9·5	8	22 3 43·23	89 54 18·1	*c*
	14	6 12	21	,,	+1 59·92	+0·01	+0·42	− 2 16·1	−0·1	− 9·5	8	22 3 43·17	89 54 16·0	*d*
	16	6 38	7	B.	−0 7·24	+0·04	+0·48	− 7 10·0	−0·6	− 9·8	1	22 0 15·89	90 42 33·8	*e*
	17	6 33	24	H.	−1 12·17	+0·09	+0·48	−14 10·9	−0·7	−10·0	3	21 58 10·97	91 10 35·7	*f*
	17	6 33	24	,,	−1 39·23	+0·01	+0·48	− 1 50·6	0·0	−10·0	3	...	...	*g*
	18	5 52	40	B.	−0 23·19	−0·01	+0·45	+ 2 24·1	+0·2	−10·2	3	21 55 57·20	91 40 21·0	*h*
	18	5 56	43	H. F.	−0 23·65	−0·01	+0·46	+ 2 27·7	+0·2	−10·2	3	21 55 56·75	91 40 24·6	*h*
	18	6 21	4	A. C.	−0 26·02	−0·02	+0·49	+ 3 6·0	+0·4	−10·2	2	21 55 54·40	91 41 3·1	*h*
	23	5 41	49	,,	+1 3·11	+0·07	+0·52	− 7 40·1	−0·6	−11·1	3	21 39 57·27	95 5 0·6	*i*
	23	5 47	39	,,	−1 58·20	0·00	+0·52	− 0 24·2	0·0	−11·0	3	21 39 56·69	95 5 12·2	*k*

Notes.

The observations are corrected for refraction and parallax. In computing the latter log Δ has been taken from Dr. Backlund's ephemeris (*Ast. Nach.*, 3263), the values used being 9·8652, 9·8594, 9·8476, 9·8417, 9·8356, and 9·8068 on January 13, 14, 16, 17, 18, and 23 respectively. The observations are also corrected for the error of inclination of the wires, and for the motion of the comet. The apparent errors of Dr. Backlund's ephemeris in R.A. and N.P.D. (Tabular−Observed) are −2ˢ·91, +17″·2 from star *a*; −3ˢ·00, +16″·0 from star *b*; −2ˢ·22, +13″·5 from star *c*; −2ˢ·16, +15″·6 from star *d*; −5ˢ·00, +41″·4 from star *e*; −3ˢ·39, +24″·5 from star *f*; −4ˢ·01, +24″·1 from star *h* (B.); −3ˢ·96, +25″·9 from star *h* (H. F.); −4ˢ·05, +19″·5 from star *h* (A. C.); −5ˢ·84, +35″·2 from star *i*; −6ˢ·24, +35″·8 from star *k*.

January 13.—Cloudy; comet very bright. January 14.—Comet faint; cloudy. January 16.—Very cloudy; observation rough. January 23.—Comet visible in fairly bright twilight.

The initials H., A. C., B., and H. F. are those of Mr. Hollis, Mr. Crommelin, Mr. Bryant, and Mr. Furner respectively.

Comparison Stars.

	Star's Name.	Assumed R.A. 1895·0. h m s	Assumed N.P.D. 1895·0. ° ′ ″	Authority.
a	Lalande, 43336	22 7 23·53	89 19 57·3	Munich, Schjellerup, and Pulkowa Catalogues.
b	W.B. XXII., 112	22 8 27·85	89 38 29·9	Göttingen and Munich Catalogues.
c	B.D. −0°, 4304	22 0 9·96	89 52 55·6	Karlsruhe and Schjellerup Catalogues.
d	W.B. XXI., 1379	22 1 43·62	89 56 35·6	Brussels, Göttingen, Munich, Pulkowa, and Radcliffe 1890 Catalogues.
e	α Aquarii	22 0 23·41	90 49 47·7	Greenwich Five-year Catalogue of Fundamental Stars, 1890.
f	32 Aquarii	21 59 23·36	91 24 50·6	Radcliffe 1860, Yarnall, Schjellerup, Glasgow 1870, Karlsruhe and Radcliffe 1890 Catalogues.
g	B.D. −1°, 4245	21 59 52·0	91 13 0·0	Bonn Observations, vol. iii.
h	W.B. XXI., 1261	21 56 20·75	91 37 59·9	Karlsruhe Catalogue.
i	W.B. XXI., 865	21 38 54·38	95 12 44·0	Yarnall, 2nd Armagh, Paris, Karlsruhe, Radcliffe 1890 and Glasgow 1890 Catalogues.
k	W.B. XXI., 938	21 41 55·17	95 5 39·1	2nd Armagh, Glasgow 1870, Karlsruhe and Radcliffe 1890 Catalogues.

Notes.

The R.A. of star *a* in Lalande is 27ˢ too great. Star *d* is the double star Σ 2862; the mean of the places of the components has been used. A proper motion of +0ˢ·0103 in R.A. has been applied to star *h*, deduced from comparison with Lalande, Weisse's Bessel, and Munich Catalogues. The R.A. of star *i* in Weisse's Bessel is 1ᵐ too small. The R.A. of star *k* in Weisse's Bessel is 50ˢ too small.

Royal Observatory, Greenwich:
1895 *February* 13.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. APRIL 10, 1895. No. 6

Dr. A. A. COMMON, LL.D., F.R.S., President, in the Chair.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Rev. J. Dunne-Parker, LL.D., Bennington House, Stevenage, Herts (proposed by Robert Wigglesworth) ;
John A. Ferguson, Newlands, Oak Hill, Surbiton, S.W. (proposed by H. B. Chamberlin) ;
George Andrews Hill, Assistant-Astronomer, United States Naval Observatory, Washington (proposed by James E. Keeler) ; and
Ernest William Hobson, M.A., Fellow of Christ's College, Cambridge (proposed by J. W. L. Glaisher).

Seventy-one presents were announced as having been received since the last meeting, including amongst others :—

Three pastel drawings of the Moon, by John Russell, R.A., presented by Mr. McClean ; eight untouched enlargements of portions of the Moon, from negative by MM. Lœwy and Puiseux, presented by Dr. L. Weinek ; an astronomical scrap album, bequeathed by the late Mrs. Jackson Gwilt.

On a Modified Form of the Cassegrain Telescope.

By William R. Brooks, M.A.

The modified form of the Cassegrain telescope with which Dr. Common has been recently experimenting was thoroughly worked out by me in 1884, and with results equally satisfactory and promising. I am glad to be able to corroborate the results so far reached by Dr. Common. The experiments made by the writer eleven years ago, were in connection with a metal speculum of seven inches aperture and about ten feet focal length, which was placed in my hands for repolishing and refiguring. It was mounted as a Herschelian, and the mirror had no central hole. Therefore, to try it as a Cassegrain, which I was anxious to do, the eye-tube was placed to one side of the large mirror. Finally the small convex mirror was placed outside the path of rays proceeding from the object to the large speculum, the eye-tube was moved by a series of trials farther from the speculum, when it was found that the distortion caused by the tilting of the large speculum could be perfectly corrected by the proper inclination of the small convex mirror, and perfect definition was the result.

A flat small mirror was also tried in place of the small convex mirror, and with equally good results. In the use of the flat small mirror no increase of the focal length resulted, and this where compactness of the instrument was sought would be a great advantage. The entire length of the telescope would then be one-half of the focal length of the large speculum.

I would here call attention to the fact that the correction of the distortion caused by the tilting of the large speculum can be corrected by the proper tilting of the small flat mirror as well as if it were convex. I consider this correction independent of the correction of the curvature of the mirrors for figure, whatever these figures of curvature may be. The result of my work in this matter led me to the opinion that whatever corrections for figure were required for the large and small mirrors when placed in the ordinary position of the Cassegrain telescope would be correct for them when the small mirror was placed outside, as in this modified form. If a flat small mirror be used, the large speculum should be parabolic.

If a convex small mirror be used, the correction for figure may be divided between the two, as commonly practised. All the advantages pointed out by Dr. Common in the direction of virtual great focal length, and hence large resultant images, with a minimum length of instrument, were fully corroborated by my tests.

The other advantages will also, it seems to me, be obvious to the practical astronomer and optician.

Circumstances prevented me from carrying these trials forward on a more extensive scale at that time, although I always hoped to resume them. I wish here to express my gratification that one so able, in every sense of the word, as our esteemed President, has undertaken to elaborate this very promising form of telescope. From my own experience I venture to predict that such work will be crowned with perfect success.

Smith Observatory, Geneva, N.Y., U.S.A.:
1895 *March* 6.

The Brachy Telescope of Messrs. Fritsch and Forster, of Vienna.

By A. A. Common, LL.D., F.R.S.

At the last meeting of this Society I mentioned that I had received a courteous letter from Mr. Fritsch, of Vienna, stating that he and Mr. Forster had invented the form of telescope I described in my note of January 8, and asking that their claim to priority in the invention should be acknowledged by the Royal Astronomical Society. I then stated that I could not allow this claim, as I had that morning read a letter (in the *English Mechanic*) from a Mr. Coates, of Manchester, in which he stated that a similar telescope was described in a book he possessed, published in 1825. Mr. Fritsch expresses surprise that I had not seen any description of the telescope, which ran through nearly all the periodicals of science. I expressly state in my paper that the only information I had was derived from Dr. Schroeder, who stated that this form of telescope had been made in Germany many years ago. From what he said I understood nothing had been published about this telescope, as he spoke of writing a paper on the theory of the form of this telescope. He gave me some data when I was thinking of making my 5-foot telescope, and I went so far as to make a 6-inch telescope on those data, which, however, did not succeed so well as I expected, nor so well as the combination I give in my note.

Mr. Coates's letter was written in answer to a letter in a previous number of the *English Mechanic*, written by Mr. W. R. Brooks, describing some experiments made in 1884, asking if he should prove to be the prior inventor (although he does not appear to have published any account before this) that the telescope should be called the "Brooksian Reflector," and so far as I can see neither Mr. Fritsch nor myself could object to this name for that form where the distortion of the image produced by oblique reflection from the concave is corrected by proper tilting of the plane mirror.

Since the last meeting Mr. Coates has kindly sent me the book he refers to in his letter. It is called *The Panorama of Art*, published in London by Fisher in 1825. I have made the

abstract which I give below, from which it will be seen that the particular form of telescope in question was undoubtedly made in England before 1825.

"Of reflecting telescopes the Gregorian is almost the only one made for common use. This preference seems to be owing to the neatness of its appearance, and to its being pointed towards objects in the same manner as refracting telescopes, rather than to any really intrinsic advantages which it has over the Newtonian construction. In all the reflecting telescopes we have noticed the diameter of the large mirror, on account of the interposition of the small one at the aperture, must be greater than would otherwise be required in order to enlighten the field of view sufficiently; and it may also be observed that, as specula have probably never been ground to a truly parabolic figure, the central part, the benefit of which is lost, is the most valuable portion of the whole because it would reflect the light

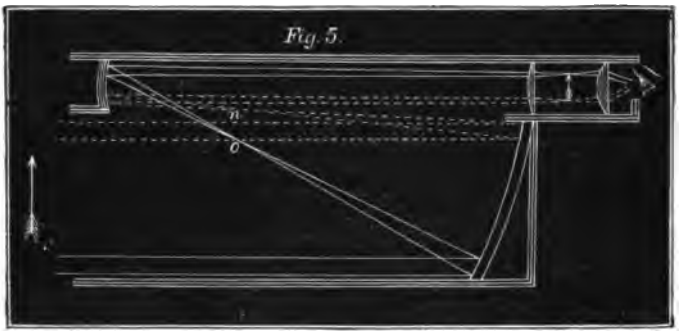


Fig. 5.

with the greatest regularity. To this it may be added that the difficulty of grinding a speculum increases perhaps in so great a proportion as the square of the diameter, and it is therefore of some importance to those who may undertake the construction of these instruments for themselves to make the large speculum as small as possible consistently with a given power and quantity of light. We shall therefore mention the form of a reflecting telescope which we recollect to have been shown many years ago by a self-taught optician, who, so far as we can recollect, on the question being put to him, declared himself to be the first who had adopted it. It is represented by fig. 5, pl. vii., where the great mirror is, as usual, at the bottom of the principal tube; but instead of having its axis coincident with that of the tube, it is inclined so as to throw the image upwards through an aperture for that purpose to *n o*, whence the rays diverge, and falling upon the small speculum are reflected by it to the eye, as in the Gregorian telescope. Here we have supposed the small mirror to be concave, but we are not certain whether it was so or not. It is clear the principle of it is pre-

served if the whole diameter of the mirror is employed to reflect light; and therefore it may have the small mirror convex like Cassegrain's reflector, or plane like Newton's. We can speak with confidence of the excellence of the instrument we allude to, and we gladly bear this testimony to the merit of an obscure individual who, we have reason to believe, is now deceased. He was tenacious of his optical knowledge, and reserved in speaking of it; yet he was far from an illiberal character. His mirrors were cast by himself in his own house, and every other part of the workmanship of his instruments, and the tools with which they were made, were constructed by himself. In solitude and silence, by day and by night, though surrounded by the chilling difficulties of poverty, he seems to have pursued his studies with an assiduity seldom paralleled; and the knowledge which it cost him so much to acquire he might feel it difficult to part with to a casual acquaintance. Perhaps the notice we have taken of him in this place may be more than is called for by any proof we have given of his abilities in the new arrangement of a telescope, but the example may be an encouragement to others, and ought not to be lost."

1895 *April* 2.

Note on the Observations for Coincidence of the Collimators in Flexure Determinations with the Transit Circle of the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

In the Introduction to the *Cape Catalogue* for 1885 Dr. Gill (p. 35) repeats the suggestion made by Professor Newcomb ("North Polar Distances of the Greenwich Transit Circle," p. 416) that a possible cause for the apparent change of flexure of the transit circle since the piercing of the cube in 1864 September may be found in the systematic error introduced in viewing the wires of the collimator through the cube. Some observations for coincidence of the wires of the N. and S. collimators, viewed respectively through the cube and with the transit circle raised, were made in 1884 and 1885 to test this point, but by inadvertence this was not mentioned in publishing the resulting flexure determinations, and the readings for coincidence of the collimator-wires by the two methods were not given. This seems a favourable opportunity for placing them on record.

Determinations of flexure were made according to the following scheme :—

(1) Ten readings of S. collimator on N. collimator through the cube.

(2) Ten circle readings on each of the collimators.

(3) Ten readings of S. collimator on N. collimator through the cube.

(4) Ten readings of S. collimator on N. collimator with the transit circle raised.

(5) Ten more readings of S. collimator on N. collimator with the transit circle raised.

(6) Ten readings of S. collimator on N. collimator through the cube.

(7) Ten circle readings on each of the collimators.

(8) Ten readings of S. collimator on N. collimator through the cube.

The reversion-prism eye-piece was employed in these observations except on 1885 May 20, so as to eliminate any personality depending on the apparent direction of measurement.

This lengthy programme was not always fully carried out.

The results of the observations, as far as they refer to the readings of the collimators, are given in the following table :—

Date.	Observer.	*Readings of Micrometer of S. on N. Collimator.* Through Cube.	Through Cube.	Transit Circle raised.	Transit Circle raised.	Through Cube.	Through Cube.
1884. d h		r	r	r	r	r	r
Sept. 8 22	A.D.	·362	·368	·362	·367	·373	·379
29 0	H.	·092	·087	·071	...	·079	...
		·084	·077	·081	...	·089	...
Oct. 5 23	T.	·413	·413	·423	·450	·464	·465
		·417	·418	·422	·451	·473	·469
20 1	H.T.	·284	·280	·279	...	·259	·267
1885.							
May 20 0	T.	·347	·353	·348	...	·350	·348

The value of 1 rev. of the micrometer is 24″·17.

On 1884 September 29 and October 5 the observers took 20 readings in each case. The means of the first and second 10 readings are set down separately.

On October 5, between the two sets of observations with the transit circle raised, readings of the N. on the S. collimator were taken. The progressive change in the readings was probably due to the Sun shining on the S. collimator.

The following table shows the means of the readings respectively through the cube and with the transit circle raised, and the differences :—

Date.	*Reading of Micrometer.* Through Cube.	Transit Circle raised.	Difference.	Difference expressed in Arc.
	r	r	r	″
Sept. 8	·370	·365	+·005	+·12
29	·086	·071	+·015	+·36
	·084	·081	+·003	+·07
Oct. 5	·439	·437	+·002	+·05
	·444	·437	+·007	+·17
20	·272	·279	−·007	−·16
May 20	·349	·348	+·001	+·02

The mean of the quantities tabulated in the last column is + 0″·09. Only one-half of this difference affects the flexure, so that the difference in the horizontal flexure obtained by taking the observations through the cube instead of with the transit circle raised is only + 0″·045.

Observations of Occultations of Stars during the Total Eclipse of the Moon on 1895 March 10, made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The night was very clear till after totality ended, so that altogether 139 occultations of stars were recorded by eleven observers: twelve of these are bracketed as being presumably erroneous, five of them are solitary observations of the disappearance of 10th or 11th magnitude stars, and the times of disappearance of two stars were noted by only two observers, and as there was a discordance of several seconds between them no reliable mean could be taken. Omitting these, there are 120 good observations of disappearance or reappearance.

The observers and instruments used are given in the following table:—

Observer's Initials.	Observer's Name.	Instrument.	Aperture. in.	Power.	Clock used.
D.	Mr. Dyson	Merz Equatorial	13	220	Dent 1793
L.	Mr. Lewis	28-inch Equatorial	28	200	Dent 2009
H.	Mr. Hollis	Guiding Telescope of Astrographic Equatorial	10	225	Dent 2017
A.C.	Mr. Crommelin	Sheepshanks Equatorial	6·7	55	Earnshaw
B.	Mr. Bryant	Altazimuth	4	100	Graham I.
G.E.N.	Mr. Niblett	Corbett Equatorial	6	200	Dent 2009
A.E.	Miss Everett	Simms' Portable Telescope, No. 1	4	60	Arnold 84*
H.F.	Mr. Furner	R. O. Detached Telescope, No. 1	4	60	Appleton 434*
C.D.	Mr. Davidson	R. O. Detached Telescope, No. 2	4	60	Loseby 111*
D.E.	Mr. Edney	R. O. Detached Telescope, No. 3	4	60	Kullberg 5226*
J.	Mr. Johns	Astrographic Equatorial	13	...	Dent 2017

* Chronometer.

The Corbett equatorial was on the same mounting as the 28-inch.

H. F. observed from the leads just south of the Sheepshanks equatorial.

C. D. and D. E. observed from the roof of the new Physical Observatory.

A. E. observed from the roof of a house, No. 18 The Circus, Greenwich, 500 yards due west of the transit circle.

Seven stars were observed both at disappearance and reappearance, the number of independent measures of chords available for determination of the Moon's diameter being 49. Unfortunately all of these are considerably to the north of the Moon's centre.

The results of the observations are given in the table below. The first column gives the name of the star, the second its magnitude. The letter in the third column indicates whether a disappearance or a reappearance was observed. The next ten columns give the seconds of Greenwich mean time of disappearance or reappearance, according to the ten observers stationed in the Royal Observatory. The next column gives the concluded mean time of the phenomenon. The last column gives the seconds of Greenwich mean time according to Miss Everett, who observed from the roof of a house (No. 18 The Circus, Greenwich) 500 yards due west of the transit circle. The corrections required to reduce her observations to those made in the Observatory are $+0^s.43$ for 83 *Leonis* (D) and $+0^s.06$ for W.B. XI. 365 (R). The correction has not been computed for the other observations.

Star's Name.	Mag.		Seconds of G.M.T. by different observers. D.	L.	H.	A. C.	B.	G. E. N.	H. F.	C. D.	D. E.	J.	Concluded G.M.T.			Seconds of G.M.T. by A. E.
			s	s	s	s	s	s	s	s	s	s	h	m	s	s
82 Leonis	6·9	D.	...	34·9	38·7	...	...	...	...	...	...	...	13	34		...
83 Leonis	6·9	D.	28·2	28·2	28·0	28·3	28·3	28·8	29·3	28·7	28·3	28·0	14	17	28·42	27·5
Pi. XI. 71	8·1	D.	6·4	6·3	6·2	6·6	6·7	6·2	(8·3)	7·0	6·4	6·8	14	18	6·52	(46·2)
Anon. *a*	10	D.	...	...	56·4	...	...	...	...	...	...	...	14	44	56·4	...
τ Leonis	5·2	D.	18·9	18·8	19·1	19·1	19·5	18·8	19·2	20·4	19·4	19·4	14	56	19·27	19·3
W.B. XI. 349	8·0	D.	32·4	32·9	32·8	33·0	32·9	(31·8)	32·0	33·3	33·5	32·8	14	56	32·84	32·8
Anon. *b*	10	D.	...	49·9	46·9	...	...	...	...	...	...	...	14	58		...
Anon. *c*	10	D.	...	24·0	...	...	...	...	...	...	...	...	15	4	24·0	...
83 Leonis	6·9	R.	6·8	(8·3)	6·3	6·9	6·8	(5·3)	6·1	7·5	7·5	5·9	15	12	6·70	6·7
Pi. XI. 71	8·1	R.	8·8	(11·4)	9·2	9·9	9·9	...	10·1	10·3	10·4	9·0	15	13	9·69	10·0
W.B. XI. 365	7·9	D.	39·8	39·1	39·0	39·5	39·5	(36·5)	39·1	39·7	39·7	39·0	15	13	39·37	39·3
B.D. + 3° 2501	9·5	R.	...	...	0·7	...	...	...	(2·1)	...	...	...	15	18	0·7	...
Anon. *d*	10	D.	...	42·0	...	...	...	...	...	...	...	...	15	20	42·0	...
Anon. *a*	10	R.	27·9	...	...	...	...	...	...	...	...	...	15	29	27·9	...
Anon. *e*	10	D.	...	43·4	...	...	...	...	...	...	...	...	15	29	43·4	...
W.B. XI. 372	8·8	D.	20·8	21·4	21·3	21·0	21·7	21·4	21·7	21·8	22·5	21·3	15	35	21·47	21·3
τ Leonis	5·2	R.	52·9	53·1	52·7	52·7	53·2	...	51·9	53·4	53·4	52·9	15	43	52·89	53·4
W.B. XI. 349	8·0	R.	(27·9)	24·5	24·7	24·8	25·2	...	25·0	25·7	25·4	25·3	15	47	25·07	25·3

Star's Name.	Mag.		Seconds of G.M.T. by different observers. D.	L.	H.	A. C.	B.	G. E. N.	H. F.	C. D.	D. F.	J.	Concluded G.M.T.	Seconds of G.M.T. by A. H.
			s	s	s	s	s	s	s	s	s	s	h m s	s
B.D. + 3° 2510	9·4	D.	...	39·8	39·6	(32·1)	...	39·9	...	...	...	(28·4)	15 57 39·76	...
W.B. XI. 365	7·9	R.	...	21·8	22·6	22·3	22·5	21·6	21·8	22·6	23·0	22·5	15 58 22·30	22·3
W.B. XI. 372	8·8	R.	...	(37·2)	30·0	30·1	30·6	...	25·6	...	30·6	...	16 9 30·17	...

Notes.

82 Leonis.—This star disappeared at the Moon's bright limb. All the other phenomena were at the eclipsed limb.

83 Leonis (D.)—A. E.'s time has been diminished 10ˢ.

Pi. XI. 71 (D.)—A. E. noted that her count of seconds was almost certainly erroneous. H. F. noted observation doubtful; wind shook instrument. Anon. *a* (D.)—Angle from Vertex towards East 45°.

τ Leonis (D.)—D. E. noted that his count of seconds was probably one second in error.

W.B. XI. 349 (D.)—D. E. noted that his count of seconds was probably one second in error.

Anon. *b* (D.)—Angle from Vertex towards East 80°. Anon. *c* (D.)—Angle from Vertex towards East 63°.

83 Leonis (R.)—C. D. noted that the star was on the edge of field.

Pi. XI. 71 (R.)—B. was doubtful if his count of seconds was correct. A. E.'s time has been diminished 10ˢ.

W.B. XI. 365 (D.)—D. noted that his count of seconds was possibly in error.

B.D. + 3°, 2501 (R.)—H. noted did not appear suddenly. H. F. noted probably late, star very faint. H. F.'s time has been diminished 1ᵐ.

Anon. *d* (D.)—Angle from Vertex to East 105°. Anon. *a* (R.)—Angle from Vertex to East 317°.

Anon. *e* (D.)—Angle from Vertex to East 45°.

W.B. XI. 372 (D.)—D.'s time has been increased 10ˢ. A. C. and A. E. both noted that this star appeared projected on the Moon's limb before disappearance.

τ Leonis (R.)—A. E.'s count of seconds interfered with by a clock striking.

B.D. + 3°, 2510 (D.)—A. C. and J. both noted the observation as doubtful; they appear to have lost sight of the star before it reached the limb.

W.B. XI. 365 (R.)—H.'s time has been diminished 1ᵐ. D. E. noted that his count of seconds was probably half a second in error. J.'s time has been diminished 10ˢ.

W.B. XI. 372 (R.)—L. noted that his count of seconds was probably six or seven seconds in error.

Observations of Contacts with Shadow.

Phenomenon.	Observer.	G.M.T. h m s
First Contact with Shadow	A. C.	13 55 4
	B.	13 53 23
Beginning of Totality	A. C.	14 52 5
	B.	14 51 55
	H. F.	14 52 6
End of Totality	A. C.	16 25 13*

Royal Observatory, Greenwich:
1895 *March* 26.

Observations of Occultations of Stars during the Total Lunar Eclipse of 1895 *March* 10 *at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

The following occultations were observed by Mr. Wickham with the 10-inch Barclay equatorial, using power 90 and solar chronometer; and by Mr. Robinson with the 7·5-inch heliometer, using power 80 and sidereal clock. The night was exceptionally fine.

Name of Star.	Mag.	Phenomenon.	Time noted. h m s	G.M.T. of Observation. h m s	Observer.
83 Leonis	7·5	Disappearance	14 17 33·3	14 15 32·1	W.
"	"	"	13 23 49·0	14 15 32·3	R.
Piazzi XI. 71	8·0	"	14 18 11·25	14 16 10·0	W.
"	"	"	13 24 27·0	14 16 10·2	R.
τ Leonis	5·0	"	14 56 24·9	14 54 23·4	W.
"	"	"	14 2 46·3	14 54 23·2	R.
W.B. XI. 349	8·2	"	14 56 42·9	14 54 41·4	W.
"	"	"	14 3 4·5	14 54 41·4	R.
83 Leonis	7·5	Reappearance	15 13 8·8	15 11 7·1	W.
"	"	"	14 (19) 32·5	15 11 6·6	R.
Piazzi XI. 71	8·0	"	15. 14 12·0	15 12 10·4	W.
"	"	"	14 (20) 35·9	15 12 9·9	R.
Arg. Z. + 3°, 2501	9·5	"	15 18 32	15 16 30·3	W.
W.B. XI. 372	8·8	Disappearance	15 35 26·3	15 33 24·5	W.
"	"	"	14 41 54·25	15 33 24·7	R.
τ Leonis	5·0	Reappearance	15 45 6·3	15 43 4·4	W.
"	"	"	14 51 35·6	15 43 4·4	R.
W.B. XI. 349	8 2	"	15 48 35·8	15 46 33·9	W.
W.B. XI. 372	8·8	"	16 10 59·8	16 8 57·7	W.

* Rough observation; cloudy.

Observers' Remarks.

Mr. Wickham: Arg. Z. + 3°, 2501.—The time noted may be 1ˢ late. Star very faint. W.B. XI. 365.—Having watched for several minutes after the predicted time, given in *The Observatory* for March 1895, for the reappearance, I had just given up the count when the star flashed out from the limb. I then picked up the count of the seconds, and on reference to the chronometer inferred the approximate time of reappearance to be $15^h\ 59^m\ 46^s$, or $15^h\ 57^m\ 44^s$ G.M.T.

At $15^h\ 36^m$ G.M.T., about the middle of the eclipse, examined the Moon by naked eye. The usual deep copper colour prevailed; the large blackish patch, occupying the centre, and diminishing in darkness towards the limb, was a striking feature of the eclipse. The effects of irradiation were strongly marked as the Moon emerged from the shadow; the illuminated portion, by contrast, appeared intensely bright, and distinctly projected beyond the darkened limb. During totality the background of the sky was very black, the Milky Way, clusters, and small stars being unusually well defined. The definition in the telescope was very good, and at totality the markings of the Moon were easily distinguished near the limb, but not at the centre.

Mr. Robinson: The observations were in every case satisfactory. All the occultations were instantaneous, excepting only the reappearance of τ Leonis, which seemed to take about $0^s{\cdot}2$ in acquiring full brightness. When the total phase of the eclipse was nearly complete the uneclipsed crescent presented a distinctly blue colour by contrast with the usual ruddy hue, which was very pronounced over the rest of the disc.

Radcliffe Observatory, Oxford:
1895 *March* 19.

Note on the Total Eclipse of the Moon, 1895 *March* 10.

By H. F. Newall, M.A.

The following occultations of stars were observed with the Newall Telescope, Cambridge Observatory, during the eclipse, under very favourable atmospheric conditions. The times were noted on a chronometer beating 100 to a minute. The writer observed within earshot of the chronometer, and at the moment of a disappearance or reappearance of a star began counting with the chronometer, having previously been attentive to the beats; his assistant, A. W. Goatcher, took up the counting and read off the chronometer.

With one exception, the recorded observations are considered certain within half a beat of the chronometer, that is, within $0^s{\cdot}3$. The recorded time for the reappearance of the star No. 5 on Dr. Döllen's list is considered possibly $0^s{\cdot}6$ late.

The observations were made with the aperture 24 inches, and with the micrometer with magnifying power 307. A micrometer wire was set so as to be a chord of a small arc of the limb of the Moon, with the observed star at the middle of the arc, as near as possible to the moment at which the star was observed to be disappearing or to have reappeared; and the parallel was determined by allowing a star to trail along the wire; from

these data the position angle measured from the north-point was determined for many of the occultations.

All the disappearances seemed to be instantaneous, without any trace of fluctuations of brightness.

The stars observed have been identified with those on Dr. Döllen's list, though the observations were made without knowledge of Dr. Döllen's list prepared for the Cambridge Observatory.

Dr. Döllen's List.				*Observations.*							
No.	Mag.	Time.	Q.	Recorded Mag.	Recorded Q.	Recorded Time.	Chronom. Slow.	Greenwich Mean Solar Time.			Phenomenon.
		h m	°		°	h m	m	h	m	s	
3	6·9	...	...	7	...	13 29·37	1·767	14	16	46·4	Disappearance. Good
4	8·1	...	...	8·5	95·22	13 29·99	1·767	14	17	23·5	„ „
5	5·2	14 56·0	83	5	85·49	14 8·23	1·768	14	55	31·7	„ „
6	8·0	14 56·2	88	9	...	14 8·38	1·768	14	55	40·7	„ „
7	7·9	15 13·3	80	9	81·06	14 25·59	1·768	15	12	50·4	„ „
...	...	...	...	10	325·84	14 43·11	1·768	15	30	18·8	Reappearance. „
10	8·8	15 34·3	67	9	68·17	14 47·43	1·769	15	34	37·3	Disappearance. „
5	5·2	15 43·6	345	5	344·88	14 55·26	1·769	15	42	25·8	Reappearance. Fair
6	8·0	15 46·2	340	9	339·61	14 58·87	1·769	15	46	1·8	„ Good
...	...	...	...	10	120·19	15 9·34	1·769	15	56	28·3	Disappearance. „

Both before and after totality the part of the shaded Moon near the edge of the shadow was grey blue, and the change of colour along a radius of the shadow-disc was as in a spectrum, grey blue at the boundary of the shadow passing through green and tawny yellow to dusky red. When the encroaching shadow-edge passed through Billy and Hansteen the limb of the Moon was already reddish, and it was noted throughout the eclipse that the dusky red was more marked on the southern parts than on the northern parts of the Moon's disc.

Occultations observed at Harrow during the Total Eclipse of the Moon, 1895 *March* 10. By Lieut.-Colonel G. L. Tupman.

		Harrow Sidereal Time.	Greenwich Mean Time.
		h m s	h m s
83 Leonis	Dis.	13 29 36·45	14 16 57·24
,,	Reap.	14 24 36·39	15 11 48·18
P. XI. 71	Reap.	14 25 39·97	15 12 51·58
τ Leonis	Dis.	14 8 32·00	14 55 46·42
,,	Reap.*	14 56 30·47	15 43 37·03
LL 21847	Dis.	14 47 41·23	15 34 49·23
LL 21819	Dis.	14 8 47·04	14 56 1·42
,,	Reap.	15 0 3·14	15 47 9·12
LL 21833	Dis.	14 25 56·71	15 13 8·28

Place of observation (about 188 feet south of the transit circle) in latitude 51° 34′ 45″·5, longitude $0^h\ 1^m\ 19^s{\cdot}86$ W. Height above sea 220 feet. The clock-correction was determined March 10 and 11.

Total Eclipse of the Moon, 1895 *March* 10. By G. J. Newbegin.

Six photographs of the lunar eclipse were taken by me at Thorpe Observatory in the focus of 9-inch Cooke equatorial: the first at 14^h, 6^m after immersion in Earth's shadow, which had by this time well advanced. The second was taken at $14^h\ 30^m$, showing the shadow so far advanced as to cover quite two-thirds of the Moon. My third plate was exposed at $14^h\ 55^m$, three minutes after commencement of total phase, the Moon still showing considerable brightness in the region last immersed, and τ *Leonis* not yet occulted. Being in doubt as to what exposure to give, I tripled it, hopeful of securing some trace of the Moon, and also the star so near occultation. Hope is one thing, reality another; the plate came out a complete blank, not the least trace of anything being visible. At $15^h\ 30^m$ I tried once more, the Moon having now reached very nearly central totality. This time I increased the former exposure twenty times, again wondering what the result might be. Result—a blank plate, with somewhat more light in it. I then decided not to expose until the emergence of the Moon from Earth's shadow, and meanwhile made only visual notes, from which I now quote:— $15^h\ 30^m$, S.E. of Moon quite copper-coloured, N.W. silver-edged.

* Reap. of τ *Leonis* was not instantaneous.

$15^h\ 50^m$, N. silver-edged. $16^h\ 10^m$, from N. to S.E. silver-edged, which region continued brightening until end of total phase at $16^h\ 26^m\ 6^s$. It would be difficult to say at what particular second one could be certain the Moon had emerged, but I feel certain the time named was extremely near. At $16^h\ 30^m$, or about $3\frac{1}{4}^m$ after emergence, I again exposed a plate, and secured a very faint segment of the reappearing Moon. My last plate was exposed at 17^h, dawn having commenced. By this time three-fifths of the Moon had reappeared, and the eclipse of 1895 March 10 was practically over.

Times of Exposure. h	s		Times of Exposure. h	s	
14	20	2-inch aperture	15·30	60	9-inch aperture
14·30	20	„ „	16·30	30	2-inch „
14·55	60	„ „	17	20	„ „

Solar Eclipse, 1895 *March* 25. By G. J. Newbegin.

On this occasion so many clouds were passing from the N.W. that I can only say my first observation of the eclipse was at $22^h\ 4^m$ G.M.T., when it had already begun, but certainly only just begun. At $22^h\ 13^m$ I took this photograph: it was then or never as far as sky was concerned. I estimate it to have been then at its maximum. At $22^h\ 24^m$ I had one more peep, when, to my eye, the eclipse was over.

Partial Eclipse of the Sun, 1895 *March* 25. By Professor Arthur A. Rambaut, M.A., Sc.D.

At Dunsink on the morning of the eclipse the sky was flecked with clouds which occasionally obscured the Sun. We missed the first contact, but the time of egress was well determined, the definition being very good at the time.

This phase occurred at $10^h\ 42^m\ 42^s{\cdot}8$ G.M.T.

Dunsink: 1895 *April* 10.

Observation of the Partial Solar Eclipse of 1895 March 25 at the Armagh Observatory. By J. L. E. Dreyer, Ph.D.

With a power of 100 on the 10-inch refractor the contacts were observed as follow :—

Beginning $21^h\ 36^m\ 1^s{\cdot}2$ Greenwich M.T.
End . 22 45 43·2 Greenwich M.T.

The definition was very good, and both observations were considered satisfactory.

Armagh Observatory:
1895 *April* 9.

Notes on the Variable Stars X and W Sagittarii.
By Lieut.-Col. E. E. Markwick.

Twenty-two observations of *X Sagittarii* have been secured in 1894, which are detailed in the table following. The first column gives the calendar date, the second the Julian, the third the observed brightness, the fourth the days elapsed from last preceding maximum calculated on Dr. Chandler's data (period, 7·01185 days) and date of observation, and the fifth the difference in days between observation and calculation. This last has been arrived at by plotting the observations on a typical curve, and measuring off their horizontal distance from the curve, those to the left being negative, and right, positive. For convenience the scale has been taken at: 1 day, horizontal, =·25 inch, 1 tenth of a magnitude, vertical, =·125 inch.

I much regret that the "O—C" column for this star on p. 141, vol. liv. of the *Monthly Notices* is incorrect. In calculating the dates of maxima for 1893 the Julian figures were correctly ascertained, but unfortunately the calendar dates were wrongly taken out by one day, and hence O—C is affected on that page with an error of one day. I have now carefully revised the figures, and the following are the results, compared with last year's observations:

X Sagittarii.	No. of Obs.	Sum of positive residuals.	Sum of Negative residuals.
1893	40	7·2	22·8
1894	22	1·8	16·2

If my observations are reliable, these figures would appear to indicate that on the whole the period is a trifle too long, and wants bringing back a very little.

X Sagittarii.

Date. 1894.	Julian, 2 410,000[1] + d	Observed brightness.	After Max. d.	O−C. d.
Aug. 20·40	3061·40	5·7	4·81	−0·8
23·43	3064·43	5·7	0·83	−2·6
25·38	3066·38	5·7	2·78	−0·8
26·38	3067·38	5·5	3·78	+0·6
27·32	3068·32	5 1	4·72	−1·5
27·37	3068·37	5·7	4·77	−0·9
28 38	3069·38	5·1	5·78	−0·4
Sept. 4·39	3076·39	5·5	5·77	−0 1
20·38	3092·38	5 2	0·73	−1·8
21·32	3093·32	5·3	1 67	−1·1
22·32	3094·32	5·4	2 67	−0·3
22·38	3094·38	5·5	2·73	−0·4
24·32	3096·32	5·6	4·67	−1·1
25·32	3097·32	5·7	5·67	0·0
25·37	3097·37	5·4	5·72	−0·2
26·31	3098·31	4·8	6·66	+0·2
29·30	3101·30	5·5	2·64	−0·5
Oct. 1·31	3103·31	5·6	4·65	−1·1
2·33	3104 33	5·9	5·67	+0·4
4·31	3106·31	5 6	0·64	−2·0
21·29	3123·29	5·7	3·60	+0·1
27·29	3129·29	5·0	2·58	+0 5

W Sagittarii.—The observations follow, arranged in the same way as those of the preceding star. I have also recomputed the observations for 1893, using Dr. Chandler's period, 7·59460 days. The results come out :

	No. of Observations.	Sum of positive residuals.	Sum of negative residuals.
1893	43	10·0	14·5
1894	26	5·1	12 5

The negative residuals in 1894 might be reduced by 2·9, by the omission of an observation on October 31, which was unreliable owing to the low altitude of the star. On the whole I do not think that the observations of 1894 are sufficiently numerous for any correction to the period to be deduced with any certainty. If the negative ones increased systematically in the future, of course the period adopted would be a little too large, but seeing that a much larger number of observations was obtained in 1893, and that the positive and negative residuals

then came out more nearly equal, it would not appear that any correction to the period is necessary at present.

The observations were made with a binocular, magnifying about five times. *W* was usually compared with 14 (U.A.) of same constellation, and *X* with F 4 *Sagittarii*.

W Sagittarii.

Date. 1894.	Julian, 2 410,000^d +	Observed brightness.	After Max. *d*.	O−C. *d*.
	d			
Aug. 20·40	3061·40	5·6	4·81	−0·7
23·43	3064·43	5·1	0·24	−1·5
25·39	3066·39	5·45	2·20	−0·5
26·38	3067·38	5·5	3·19	+0·2
26·43	3067·43	5·5	3·24	+0·2
27·32	3068·32	5·8	4·13	−0·4
27 37	3068·37	5 8	4·18	−0·4
28·38	3069·38	5·5	5·19	−0·6
Sept. 4·39	3076·39	5·8	4·61	+0·2
16·32	3088·32	5·0	1·35	0·0
20·38	3092·38	5·8	5·41	+0·9
21·32	3093·32	4·9	6·35	−0·5
22·32	3094·32	5·2	7·35	+1·1
22·38	3094·38	5 1	7·41	+1·0
24·32	3096·32	5·1	1·76	0·0
25·32	3097·32	5·5	2·76	−0·2
25 37	3097·37	5·5	2·81	−0·2
26·31	3098·31	5 9	3·75	−0·8
29·30	3101·30	5·0	6·74	+0·1
Oct. 1·31	3103·31	5·3	1·15	−1·2
2·32	3104·32	5·55	2·16	−1·0
4·31	3106·31	5 7	4·15	+0·5
21·29	3123·29	5·6	5·94	+0·4
24·30	3126·30	5·5	1·36	−1·6
27·29	3129·29	5·75	4·35	+0·5
31·30	3133·30	5·7	0·76	−2·9

Gibraltar:
1895 *February.*

η Cassiopeiæ. By Thomas Lewis.

In the *Monthly Notices*, vol. lv. 1, 1894 November, in my remarks on the orbit of *η Cassiopeiæ*, on page 20, "the combined mass is 3·54" should read "the combined mass is 1·69."

I take this opportunity of sending an extract from a letter received from Mr. Hermann S. Davis, Columbia College, New York, at the same time remarking that the parallaxes used were derived from Professor Pritchard's list. "I have only recently completed a determination of parallax for this star from Rutherfurd photograph measures, using six pairs of comparison stars, the result being

$$\pi = +0''\cdot443 \pm ''\cdot043.$$

Referring to Socoloff's reduction of Schweizer's observations (*Annales de l'Observatoire de Moscou*, vol. iii. part 2), I find that the values of π given there are

$$+0''\cdot3743 \pm ''\cdot0723 \text{ in distance}$$

and

$$+0''\cdot1386 \pm ''\cdot0849 \text{ in position,}$$

whereas you have $0''\cdot202$ and $0''\cdot139$ respectively in your article. The former value is obtained by assuming that the negative sign of the coefficient k, on page 88 (*Annales*), is a misprint for +.

"If, however, we adopt the author's own interpretation, we get $0''\cdot374$, as given on page 89 (*Annales*)."

With this corrected value and Mr. Davis's new result, the mean parallax of *η Cassiopeiæ* is $0''\cdot285$.

1895 *March* 30.

Equatorial Comparisons of Jupiter and 1 *Geminorum*, 1895 *January* 5 *and* 10. By John Tebbutt.

In consequence of cloudy weather, which has prevailed here almost uninterruptedly since the beginning of the year, I only succeeded in getting comparisons of *Jupiter* and 1 *Geminorum* on two nights with the filar micrometer on the 8-inch equatorial. On January 5 I obtained twenty-four comparisons on the single thread of the micrometer, in each of which both limbs of the planet were observed, the corresponding comparisons for difference of declination being equally divided between the north and south limbs. On the 10th twenty comparisons were similarly made. The corrections for phase and refraction are in-

sensible. The planet's semidiameter on page 280 of the *Nautical Almanac* is employed in the reductions of the differences of declination from the limbs to the centre, and the mean place of the star is derived from the Greenwich Five-year Catalogue of 258 fundamental stars. The tabular places of the planet are interpolated with second differences from page 250 of the *Nautical Almanac*. As the steadiness and definition of the objects were satisfactory, it is hoped that the tabular corrections will bear favourable comparison with those derived from meridian observations.

	d	h m s	d	h m s
Windsor M.T. of mean of transit of planet's centre	Jan. 5	12 50 8	Jan. 10	10 46 35
		h m s		h m s
Adopted mean R.A. of star for 1895·0 ...		5 57 44·20		5 57 44·20
Reduction to apparent R.A. for date ...		+ 1·62		+ 1·64
Planet's centre−star		− 4·43		−2 41·19
Correction for parallax		+ 0·06		+ 0·01
Concluded geocentric apparent R.A. of planet		5 57 41·45		5 55 4·66
Geocentric apparent R.A. from *Nautical Almanac*		5 57 41·14		5 55 4·26
Correction for *Nautical Almanac*		+ 0·31		+ 0·40
		° ′ ″		° ′ ″
Adopted mean Declin. of star for 1895·0 ...		+23 16 6·8		+23 16 6·8
Reduction to apparent Declin. for date ...		+ 8·7		+ 8·7
Planet's centre−star		−41·9		− 9·0
Correction for parallax		− 1·7		− 1·8
Concluded geocentric apparent Declin. of planet		+23 15 31·9		+23 16 4·7
Geocentric apparent Declin. from *Nautical Almanac*		+23 15 32·0		+23 16 4·2
Correction for *Nautical Almanac*		− 0·1		+ 0·5

The Observatory, Windsor, N.S. Wales:
1895 *February* 3.

Occultation of Antares, 1894 *October* 31. By R. T. A. Innes.

I observed this occultation using Mr. W. F. Gale's 6¼-inch refractor, by T. Cooke. Power of eye-piece about 190. The disappearance in sunlight was instantaneous; the reappearance was after sunset, but still in strong daylight. My eye was fortunately fixed on the spot of reappearance. I noticed a faint bluish light, which, whilst I was wondering what it was, seemed to stretch towards the Moon's limb; then *Antares* flashed out ruddy and all but instantaneously. I then saw that the faint light which I first perceived was the companion, which was immediately well separated from *Antares*. I called two ladies who were near the telescope, and they both saw the companion without any prompting. Until *Antares* emerged the companion seemed to be connected with it or the Moon's limb by an electric arc. Definition perfect.

Sydney:
1895 *February* 21.

Pallas and Vesta in 1895. By W. W. Bryant.

Pallas is very well placed this year for observation in the northern hemisphere, and as it might be interesting to take differential observations of it in comparison with bright stars, such as are easily within reach of small telescopes, I have made out a list of some such stars (within the limits of the B.A. Catalogue) as lie nearly in the track of the planet.

I have done the same for *Vesta*, though its south declination makes it much less convenient, especially as it makes it rise so late for some time. Still it passes near some well-known stars, notably δ *Aquarii*.

Pallas.

Date.	Star's Name	Mag.	Mean for Year. R.A.	Mean for Year. Decl.	Planet's place at Greenwich. Mean Midnight. R.A.	Planet's place at Greenwich. Mean Midnight. Decl.	Daily Change of Decl.	Approximate Civil Time of Rising.	Approximate Civil Time of Setting.
			h m	° ′	h m	° ′	′		
May 21	79 Herculis	6	17 33·2	+24 22	17 35·4	+24 20	+ 6½	Up all night.	
June 30	62 Herculis	7½	17 4·2	+24 38	17 3·1	+24 39	− 5	Sets just before sunrise.	
Aug. 9	54 Herculis	5½	16 50·8	+18 36	16 50·6	+18 34	−11	...	3.30 A.M.
Aug. 25	B.F. 2341	6½	16 53·9	+15 36	16 54·6	+15 31	−11	...	2 A.M.
Aug. 27	B.F. 2345	6	16 56·8	+15 6	16 55·5	+15 8	−11	...	...
Sept. 1	Bradley 2163	5½	16 58·3	+14 15	16 57·9	+14 12	−11	...	...
Sept. 4	Bradley 2164	6½	16 58·8	+13 45	16 59·5	+13 38	−11	...	...
Sept. 4	Bradley 2166	6	16 59·1	+13 43					
Sept. 8	60 Herculis	5	17 0·5	+12 53	17 1·9	+12 54	−11	...	1 A.M.

Vesta.

May 10	ι Aquarii	4½	22 0·8	−14 23	22 2·1	−14 23	− 4½	2 A.M.	...
May 18	45 Aquarii	6	22 13·4	−13 50	22 13·5	−13 49	− 3½	1.30 A.M.	...
May 25	Bradley 2961	6½	22 24·4	−13 27	22 22·0	−13 28	− 3	1 A.M.	...
July 7	Piazzi XXII. 264	7	22 54 1	−13 38	22 54·1	−13 37	+ 3	11 P.M.	...
Aug. 2	δ Aquarii	3	22 49·1	−16 23	22 49·6	−16 23	+ 8	9 P.M.	...
Aug. 5	77 Aquarii	6	22 49·2	−16 50	22 47·8	−16 47	+ 8	9 P.M.	...
Sept. 17	41 Aquarii	6	22 8·5	−21 36	22 12·4	−21 37	+ 2	...	2.30 A.M.
Oct. 7	Piazzi XXI. 419	7	22 5·2	−21 45	22 4 9	−21 46	− 1½	...	1 A.M.
Nov. 20	61 Aquarii	6½	22 30·2	−18 0	22 26·4	−18 2	− 7	...	11 P.M.

Note.—May 9–17 and Aug. 5–13 *Saturn* is near κ *Virginis* and 96 *Virginis*.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. MAY 10, 1895. No. 7

Dr. A. A. COMMON, LL.D., F.R.S., President, in the Chair.

Andrew Russell Forsyth, Sc.D., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge;
John Willoughby Meares, Clive Hall, Shrewsbury; and
William Willett, Junr., The Cedars, Chislehurst Common, Kent, and 2 Sloane Gardens, S.W.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:

Antoine d'Abbadie, Membre de l'Académie des Sciences, 120 Rue du Bac, Paris (proposed by G. H. Darwin);
Loyal H. Bradford, of North Ferrisburgh, Vermont, U.S.A. (proposed by Lewis Swift); and
Oswald Thomas Tuck, Naval Instructor, School Ship *Conway*, Birkenhead (proposed by E. W. Maunder).

Seventy-six presents were announced as having been received since the last meeting, including, amongst others:—

T. G. Elger, The Moon, presented by the author; Lund Observatory, Observations de la Zone entre 35° et 40°, presented by the Observatory; twelve photographs of a globe of *Mars*, prepared from drawings made at the Lowell Observatory, Arizona, presented by Percival Lowell; eight photographic enlargements of portions of the Moon, from negatives by Lœwy and Puiseux,

presented by Dr. Weinek; photographs of *Orion*, the Milky Way, &c. (negative, lantern slides, and enlargements), presented by Dr. Sheldon; lantern slide from negative of the Cluster in *Hercules*, presented by W. E. Wilson.

Answer to an Inquiry in the "Bulletin Astronomique" for May 1895, *p.* 233. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

In the *Bulletin Astronomique* for May 1895 there is a short notice of my paper, "On Some Points connected with the Integration of the Differential Equations of the Relative Motions of Material Systems" (which appeared in the *Monthly Notices* for 1894 June), which very clearly and concisely states the fundamental point of my paper to be the unchangeableness of the fundamental constant, f; but adds: "Il serait à désirer que M. Stone formulât d'une manière nette et précise les critiques qu'il sous-entend en parlant de conditions incompatibles entre la variable représentant le temps et les observations."

I have no difficulty in answering this very reasonable request.

If we denote the geocentric co-ordinates of the Sun under the usual forms

$$2\pi\iota + \odot = l + nt + \lambda t^2 \,\&c. + \int A \sin(at + \beta),$$

$$\frac{1}{r} = \&c.$$

$$\beta = \&c.$$

where $\int$ denotes a definite number of periodical terms, then in the mathematical investigations of the disturbances of the elliptic motions the effects of all the terms in the geocentric co-ordinates of the Sun, including those which are themselves due to planetary and lunar disturbance, are duly investigated subject to the condition

$$\delta[n(t+\tau)] = 0,$$

or, with *exact* values of t and a definite epoch,

$$\delta n(t+\tau) = 0,$$

and included in the different theoretical expressions of the geocentric co-ordinates of the Moon and planets.

If any long inequality,

$$P \,.\, \sin(pt + q),$$

has been omitted in the expressions for $\odot$, $\frac{1}{r}$, and β, the theoretical determination of the disturbing effects cannot be regarded as complete until those due to this term have been investigated, and, if found sensible, included in the theoretical expressions of the Moon and planets.

The resulting theoretical expressions for the geocentric coordinates of the Moon and of the planets can thus be made complete; but they will only be exact when the conditions under which they have been mathematically investigated are fulfilled; and the condition $\delta n\ (t+\tau)$ requires that the variable t, with which the theoretical expressions are compared with observation, should satisfy the condition

$$(1) \quad . \quad . \quad . \quad . \quad 2\pi\iota + \odot = n\tau + nt + \lambda t^2 + \mathrm{P} \cdot \sin(pt+q) + \int \mathrm{A} \sin(at+\beta)$$

with the value of n, which is used to fix the numerical value of f, or to eliminate that symbol from the mathematical formulæ, and the value of $\tau = \frac{l}{n}$ which has been used to render definite the instant from which t is measured.

But if the theoretical expressions of the geocentric coordinates of the centres of gravity are expressed as functions of the variable t, which satisfies the equation (1) with assigned values of l and n, we must express the right ascensions of the meridians as functions of the same variable; and if α is the right ascension of an observer's meridian, we shall have

$$(2) \quad . \quad . \quad . \quad . \quad . \quad . \quad 2\pi\iota + \alpha = \mathrm{A} + \Omega t + \sigma t^2 + \mathrm{N}ut.$$

where A and Ω are constants which cannot be found except from a discussion of observations. The values of A and Ω, which will for a definite meridian correspond to assigned values l and n in the equation (1), can only be approximately assigned at the present time. But they will be expressible under the forms

$$\mathrm{A} = l + \delta l. \qquad \Omega = \left(\frac{2\pi}{\mathrm{N}o} + 1\right) n,$$

where δl and No are unknown quantities, to be found from the discussion of observations; and we can, if we please, put

$$No = \frac{n + \delta n}{365{\cdot}25}.$$

We have then to find the quantities δl and δn from a discussion of the observations.

But if we neglect the terms δl and δn in the equations

$$(3) \quad . \quad . \quad . \quad 2\pi\iota + \alpha = l + \delta l + \left(\frac{2\pi \times 365{\cdot}25}{n + \delta n} + 1\right) nt + \sigma t^2 + \mathrm{N}ut.$$

in comparing the results of theory with observations, either directly or in finding the value of the variable from the observed right ascensions, we, at once, by the neglect of the terms δl and δn, introduce between the facts of observation, α, and the variable t, employed in the theoretical investigations, impossible conditions; and these are the incompatible conditions between the variable representing the time and the observations to which I refer.

1894.	Greenwich Mean Time. h m	Observed Distance.	Correction for Phase.	Corrected Distance.	Distance at Distance Unity.	Position Angle.	
		"	"	"	"	°	
Oct. 19	11 1·39	31·25	...	...	13·59	...	
	16·36	28 82	...	...	12·54	...	
	23·33	28·66	...	...	12·47	...	
	25·55	28·53	...	...	12·41	...	Observations interrupted by cloud.
	46 27	...	...	...	...	228·33	Mean of two obns. 228·63, 228·03.
	53·25	24·93	...	...	10·85	...	
	57·24	24·02	...	...	10·47	...	Observations stopped by cloud.
Oct. 26	11 20 31	27·97	...	...	12·51	...	
	22·81	28·68	...	...	12·82	233 48	
	32·78	27·49	...	...	12·29	231·98	
	12 2 69	26·84	...	...	12·00	224·57	
Nov. 6	10 44·66	22·98	−0·13	22·84	11·02	...	
	52·64	23·57	−0·13	23·44	11·31	...	
	55·63	24·35	0·13	24·21	11·69	...	
	57·62	24·93	0·13	24·79	11·97	...	
	...	...	...	...	...	64·55	
	11 3·61	26·59	0·13	26 46	12·77	...	
	10·09	26·35	0·13	26·22	12·65	...	
	12·59	26·69	0·13	26·56	12·82	...	
	13 59	26·69	0·13	26·55	12·82	...	

slipping piece was moved during the measurements. *Mars* was brought by moving the telescope into such position that equal segments were cut off by A_3 and A_4, and that FF bisected the disc; the slow motion in R.A. is actuated electrically.

The position circle is turned till FF also passes through the satellite, and B is moved up to bisect the satellite.

The procedure finally adopted was—

(i) To centre the planet on FF and A_3A_5.
(ii) To turn FF to bisect the satellite, or rather to put FF a little ahead of the satellite in its apparent orbit.
(iii) To move up B to bisect the satellite when it reached FF.
(iv) To begin counting with the chronometer when the double bisection was satisfactory.
(v) To look back to the planet to verify the centering.
(vi) To read the chronometer, if centering and bisection were both satisfactory.
(vii) To read the micrometer and position circle at leisure, or to start again afresh if the requirements were not satisfied.

It was decided to adopt this somewhat troublesome method of procedure rather than to make use of the convenient slipping piece and take several readings of distance and position angles separately, because the first attempts to make measurements showed how rapid the motion of the satellite was, and it seemed best to concentrate effort and care on a single set of simultaneous values of position angle, distance, and epoch.

It will be seen that there are fifty-four observations recorded, sixteen referring to western elongations on three nights, the remaining thirty-eight referring to eastern elongations on three nights.

A correction for phase was applied, based on the assumption that the measurements referred to the centre of gravity of the illuminated disc of *Mars*:

$$\Delta s = \frac{4a}{3\pi} \sin^2 \frac{E}{2} \cos (p - Q),$$

where a (apparent diameter), E (areocentric angle between Earth and Sun), p (position angle), and Q (position angle of greatest defect in illumination) had values assigned by interpolation from Marth's valuable ephemerides (*Monthly Notices*, vol. liv. pp. 394 and 557). The interval between the fixed wires A_3 and A_5 was small enough compared with the apparent diameter to make it probable that the "centre of gravity" correction would be nearer the mark than a correction based on the idea that the observed centre was midway between the terminator and the limb.

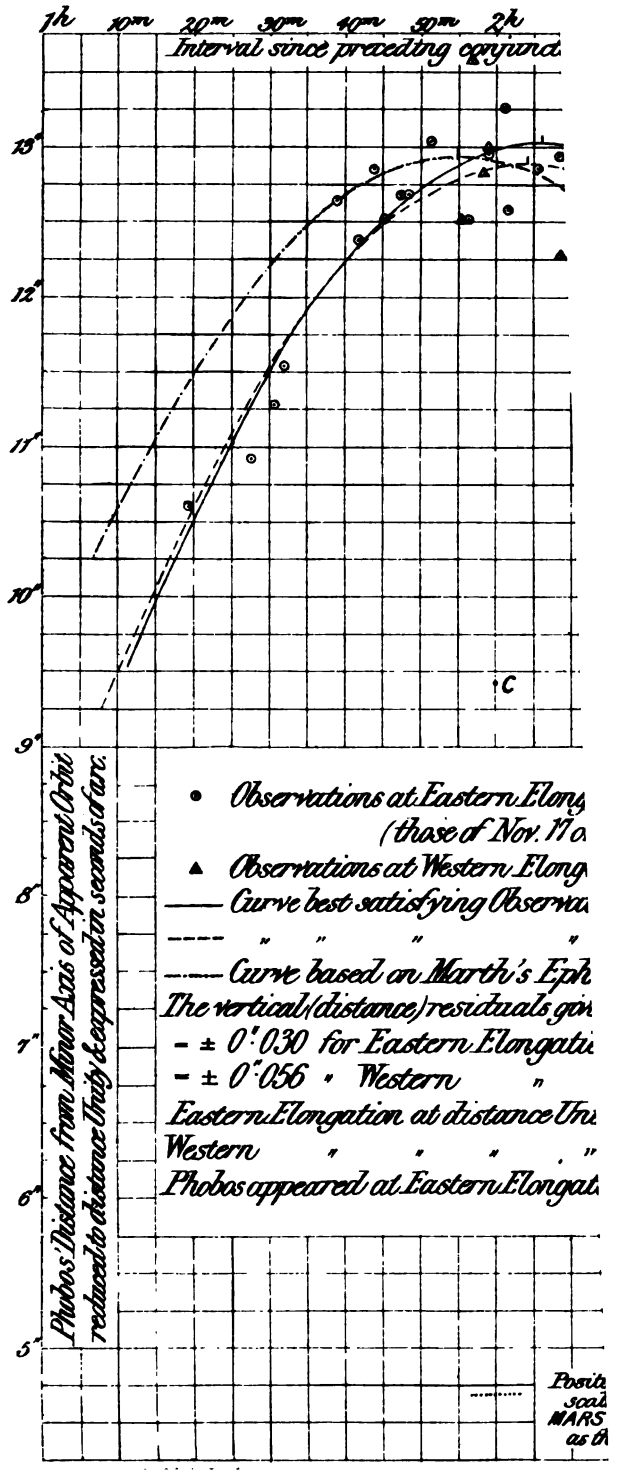
The phase correction was not applied to the position angle, such correction seldom amounting to $0^{\circ}\cdot01$. Nor was any correction for refraction made.

I am indebted to my assistant, A. W. Goatcher, for efficient help rendered during these observations.

1894.	Greenwich Mean Time. h m	Observed Distance.	Correction for Phase.	Corrected Distance.	Distance at Distance Unity.	Position Angle.	
		"	"	"	"	°	
Oct. 19	11 1·39	31·25	...	...	13·59	...	
	16·36	28 82	...	...	12·54	...	
	23·33	28·66	...	...	12·47	...	
	25·55	28·53	...	...	12·41	...	Observations interrupted by cloud.
	46 27	...	...	...	...	228·33	Mean of two obns. 228·63, 228·03.
	53·25	24·93	...	...	10·85	...	
	57·24	24·02	...	...	10·47	...	Observations stopped by cloud.
Oct. 26	11 20 31	27·97	...	...	12·51	...	
	22·81	28·68	...	...	12·82	233 48	
	32·78	27·49	...	...	12·29	231·98	
	12 2 69	26·84	...	...	12·00	224·57	
Nov. 6	10 44·66	22·98	−0·13	22·84	11·02	...	
	52·64	23·57	−0·13	23·44	11·31	...	
	55·63	24·35	0·13	24·21	11·69	...	
	57·62	24·93	0·13	24·79	11·97	...	
	...	...	...	...	...	64·55	
	11 3·61	26·59	0·13	26 46	12·77	...	
	10·09	26·35	0·13	26·22	12·65	...	
	12·59	26·69	0·13	26·56	12·82	...	
	13 59	26·69	0·13	26·55	12·82	...	

1894.	Greenwich Mean Time. h m	Observed Distance.	Correction for Phase.	Corrected Distance.	Distance at Distance Unity.	Position Angle.	
Nov. 6	11 21·56	26″·36	0″·13	26″·23	12″·66	° ...	
	26·55	26·55	0·13	26·41	12·75	...	
	29·56	...	...	...	...	54·33	
	33·53	26·90	0·13	26·77	12·92	...	
	38·02	26·48	0·13	26·35	12·72	...	Observations interrupted by cloud.
	48·49	...	...	...	...	48·69	
	50·98	26·38	0·13	26·25	12·67	...	
	52·48	25·83	0·13	25·69	12·40	...	
	59·46	25·55	0·13	25·42	12·27	...	
	12 2·35	24·86	0·13	24·72	11·94	...	
	4·34	25·02	0·13	24·89	12·02	...	
	5·44	...	...	...	...	40·10	
	8·40	24·87	0·13	24·75	11·95	...	
	9·40	24·31	0·13	24·18	11·67	...	
	11·40	23·45	0·13	23·32	11·26	...	
	12·40	23·59	0·13	23·46	11·33	...	
	13·40	22·79	0·13	22·67	10·94	...	
	19·40	22·16	0·13	22·03	10·64	...	
	29·38	21·45	0·13	21·32	10·30	...	Observations stopped by clouds.
Nov. 15	9 22·66	24·12	−0·25	23·86	12·53	65·43	

1894.	Greenwich Mean Time. h	m	Observed Distance.	Correction for Phase.	Corrected Distance.	Distance at Distance Unity.	Position Angle.	
			″	″	″	″	°	
Nov. 15	9	25·95	24·81	−0·25	24·57	12·89	60·78	
		33·93	25·11	0·25	24·86	13·05	58·74	
		40·91	24·92	0·25	24·68	12·95	55·68	
		43·90	25·50	0·25	25·25	13·26	57·40	
		47·39	24·71	0·25	24·46	12·84	54·51	
		51·38	24·85	0·25	24·60	12·92	55·41	
		54·57	25·33	0·24	25·09	13·17	51·10	Telescope reversed.
	10	28·88	22·31	0·22	22·09	11·60	39·23	
		35·46	20·43	0·22	20·21	10·62	38·16	
		48·65	18·53	0·22	18·31	9·62	36·29	
Nov. 17	7	16·29	24·08	−0·27	23·80	12·74	63·80	Bad seeing.
		30·26	22·28	0·27	22·01	11·78	59·59	
		40·09	24·03	0·27	23·76	12·15	57·12	Observations stopped by cloud.
Nov. 19	9	19·85	23·41	+0·29	23·71	12·97	236·71	Seeing very variable: often necessary to wait for many minutes.
		36·83	23·34	0·29	23·63	12·93	233·17	
		42·54	22·05	0·28	22·34	12·23	228·88	
	10	8·30	19·60	0·27	19·87	10·88	219·62	
		15·02	18·86	0·26	19·12	10·47	218·15	
		21·92	18·28	0·26	18·53	10·15	215·59	


1h 10m 20m 30m 40m 50m 2h
Interval since preceding opposit
13"
12"
11"
10"
9"
8"
7"
6"
5"
C
Phobos' Distance from Minor Axis of Apparent Orbit
reduced to distance Unity & expressed in seconds of arc.
• Observations at Eastern Elong
(those of Nov. 17 o
▲ Observations at Western Elong
—— Curve best satisfying Observa
---- " " " "
—— Curve based on Marth's Eph
The vertical (distance) residuals giv
= ± 0".030 for Eastern Elongati
= ± 0".056 " Western "
Eastern Elongation at distance Uni
Western " " " "
Phobos appeared at Eastern Elongat
Positi
scal
MARS
as O

A simple graphical method of getting a survey of the observed places suggested itself. The corrected values were reduced to distance unity, and the intervals that had passed since the last conjunction of the satellite with the planet, as deduced from Marth's Ephemeris, were determined. All the observations were thus available for plotting on a single curve. It was decided to deal with distances measured parallel to the major axis of the apparent orbit, and therefore a correcting factor $[\cos \{p \sim (P \pm 90)\}]$ was applied to the reduced distances. If the orbit were circular, the curve obtained by plotting the time and the distance parallel to the major axis would be a curve of sines. It was expected that a suitable sine-curve-template moved about among the plotted observations would reveal discrepancies. It appears that the time devoted would probably have been better spent on the laborious method of least squares. It is, however, perhaps not without interest to show the results of plotting the observations (see Plate 6), for they at any rate bring to light that the adopted periodic time of *Phobos* needs a slight correction, *Phobos* being between nine and eleven minutes later than Marth's Ephemeris.*

It is not improbable that the error in the time of elongation of *Phobos* has been accumulating since one of the oppositions shortly after its discovery. Such a belatedness as nine minutes shows either that we are not entitled to use the three figures after the decimal point in the seconds in the periodic time, or that a change in period has occurred.

It seems almost unjustifiable to compare the results of these scanty observations with those of the splendid set of measurements recently published by W. W. Campbell (*Ast. Journ.* vol. xv. p. 1). There appears in my observations evidence of differences between eastern and western elongation-distances of the same kind as those which Professor Campbell's observations establish; it should, however, be noted that my observations at western elongation were not so numerous or satisfactory as those at eastern elongation. Professor Campbell notes that his observations show that *Phobos* is $6^m \pm$ later than Marth's Ephemeris.

* Having experienced the great serviceableness of these valuable ephemerides, perhaps I may be allowed to suggest that a short prefatory note detailing the data used and the sources from which they are derived would be very useful.

On the Rotation of Saturn in 1894. By A. Stanley Williams.

The observations of spots in 1894 were made and reduced in the same manner and with the precautions described in my paper in the *Monthly Notices*, vol. liv. p. 298 *et seq.* The periods of rotation of the different spots have also been determined in the way indicated in that paper. These periods are based, therefore, upon Mr. Marth's Ephemeris contained in the *Monthly Notices*, vol. liv. p. 163.* The observations attributed to Herr Brenner are the result of measures of two drawings made with the 7-inch refractor of the Manora Observatory, and published in the *English Mechanic*, vol. lx. p. 364. These positions are necessarily only approximate, though they agree closely enough with the other observations to make the identification of the different spots certain. I have assumed the light interspaces between the dark markings shown by Herr Brenner just north of the ring to be identical with the bright equatorial spots. The observations of Mr. G. L. Brown, of Stirling, and Mr. H. MacEwen, of Glasgow, have been communicated to me direct by the respective observers.

The observations of 1894 are on the whole remarkably accordant, the agreement being even more satisfactory than it was in the preceding year. They are in fact so accurate that they have brought to light a rather remarkable peculiarity. On looking through the observations of the different spots it will be noticed as quite a usual thing for those of an individual spot to be best represented not by a uniform period of rotation, but by one with a continual change in its length. In other words, the observations when projected upon a chart are best represented by a slightly curved line, instead of by a straight one, as they should be if the motion of the spot had been uniform. As instances of this peculiarity the bright equatorial spots 1, 2, 5, 6, 8, 10, 11, 13, 15 and the dark northern spots I., II., III., IV., V., VI., VII., VIII., X., may be mentioned. Thus out of twenty-six spots eighteen show the peculiarity in question, which appears to be masked in the case of the remaining spots by the accidental errors of the observations, or from the latter being too few in number or too close together to show it. Only with spots IX. and XI. is there any decided tendency shown of a similar peculiarity, but in the opposite direction.

As to the cause of this rather remarkable feature, it hardly seems likely that it could have been due to a real physical change

* In 1893 the period of rotation corresponding to the Ephemeris was inadvertently assumed to be $10^h\ 13^m{\cdot}64$, instead of $10^h\ 13^m{\cdot}636$, the more correct value. In consequence of this, all the rotation periods of that year contained in the paper referred to above should be diminished by $0^s{\cdot}2$.

on *Saturn*, since the same variation is found both in the equatorial zone and in the zone of the dark northern spots, two regions situated at a great distance from each other and possessed moreover of greatly differing rates of rotation. It may perhaps, with more probability, be ascribed to a change in the personal equation of the observer, there being possibly a tendency for the transits to be observed later in the middle of a series of observations than at the ends, when the spots would be more difficult to observe.

In the tables of observations, the column headed T contains the G.M.T. of transit of the spot, and that headed T′ these times reduced to one date by means of the adopted rotation period of the spot, with, in the following column, the differences from the mean. The other columns explain themselves. The longitudes are derived from Mr. Marth's Ephemeris. The abbreviations used in the descriptive notes are as before : S = small, vS = very small, eS = exceedingly small, B = bright, mB = moderately bright, F = faint, vF = very faint, D = dark, v = very, e = exceedingly, m = moderately.

The Dark Spots in the Northern Hemisphere.

These dark spots were similar to those observed in 1893, and occupied the same situation on a conspicuous double belt in the planet's northern hemisphere. But in 1894 they were observed more frequently to project south of the dark belt into the bright equatorial zone, and to a greater extent. This peculiarity was noted independently by Messrs. Brenner, Brown, and MacEwen. The spots were not seen double so frequently as they had been in the preceding year.

Dark Spot I.

Date.	T.	Long.	Weight.	T′.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 4	14 31·6	327·6	1·5	10 43·4	+ 1·4	10 14 62·1	*a*
Apr. 18	10 42·3	53·0	2	42·3	− 0·1	66·1	*b*
27	10 1·3	72·6	1	46·4	+ 4·0	64·7	*c*
May 3	9 32·7	84·9	1	47·7	+ 5·3	63·7	*d*
June 13	9 21·3	154·4	2	32·1	−10·3	55·7	*e*

Description.—(*a*) S, mD, chiefly on south band of the double belt and projecting S. of it, much elong. N. and S. (*b*) vS, F. (*c*) S, F, much elong. N. and S. (*d*) S, mD. (*e*) S, F, elong. N. and S.

Mean period of rotation = $10^h\ 15^m\ 2^s{\cdot}0 \pm 1^s{\cdot}38$ (236 rotations). On three nights the spot was noted as being elongated in a north and south direction.

Dark Spot II.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 20	16 1·3	321·5	2	12 38·1	− 4·6	10 14 62·1	*a*
Mar. 31	12 45·6	37·6	1	45·6	+ 2·9	58·1	*b*
Apr. 9	11 58·0	53·6	1	44·7	+ 2·0	57·3	*c*
21	10 53·7	74·3	2	42·4	− 0·3	56·3	*d*
June 1	(10 43·2)	145·4	...	(34·9)	(− 7·8)	...	*e*

Description.—(*a*) vS, eF, projecting south of belt. (*b*) Obs. by MacEwen. Described as a faint spot on the belt, with a very faint streak extending in a s.f. direction from it across the bright equat. zone. (*c*) eS, eF. (*d*) vS, vF. (*e*) Obs. by Brenner. Spot projected south of the belt into the bright equat. zone.

Mean period of rotation = $10^h\ 14^m\ 58^s{\cdot}7 \pm 0^s{\cdot}97$ (140 rotations). On three nights an extension of the spot southwards into the bright equatorial zone was recorded by three different observers.

Dark Spot III.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 25	13 46·2	43·8	1	11 24·7	− 2·6	10 14 58·9	*a*
Apr. 18	11 41·0	87·5	0·5	25·4	− 1·9	58·4	*b*
21	11 28·4	94·6	1	28·4	+ 1·1	58·6	*c*
June 13	10 25·6	192·1	1	31·3	+ 4·0	56·2	*d*
25	9 20·9	211·0	1	26·6	− 0·7	54·7	*e*

Description.—(*a*) No description possible, def. bad. (*b*) vS, F. (*c*) vS, F. (*d*) Spot seemed plain and to project south of belt, but image dim through haze. (*e*) S, mD, perhaps projecting south of belt.

Mean period of rotation = $10^h\ 14^m\ 57^s{\cdot}2 \pm 0^s{\cdot}57$ (215 rotations). The accordance of the observations is very satisfactory. On two nights the spot seemed to project south of the belt.

Dark Spot IV.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 20	17 40·5	19·8	1	12 36 7	− 3·3	10 14 60·4	*a*
Mar. 2	13 29·7	41·5	0·5	44·2	+ 4·2	57·9	*b*
16	15 37·0	64·8	2	41·5	+ 1·5	54·7	*c*
Apr. 18	12 40·1	122·1	2	40·1	+ 0·1	54·4	*d*
19	(9 9·3)	123·3	...	(39·5)	(− 0·5)	...	*e*
May 21	9 44·8	178 6	2	37·3	− 2·7	53·9	*f*

Description.—(*a*) vS, eF. (*b*) vS, vF. (*c*) vS, F. (*d*) vS, F. (*e*) Obs. by Brown. The spot projected distinctly into the bright equat. zone. Time from measures of a sketch. (*f*) Two eS, mD spots, the south one suspected to project into the equat. zone.

Mean period of rotation = $10^h\ 14^m\ 55^s{\cdot}4 \pm 0^s{\cdot}73$ (210 rotations). The observations are in very satisfactory agreement.

Dark Spot V.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 3	16 52·0	28·0	0·5	13 63·1	+ 1·8	10 13 43·9	*a*
Mar. 2	14 14·0	67·5	1	60·5	− 0·8	45·6	*b*
8	13 39·6	76·8	2	60·7	− 0·6	46·0	*c*
22	15 53·3	103·7	3	70·0	+ 8·7	44·5	*d*
29	11 45·2	112·4	0·5	67 1	+ 5·8	44·3	*e*
Apr. 1	11 11·8	107·5	1	50·9	−10·4	44·8	*f*
9	14 12	125·9	1	61·2	− 0·1	42·4	*g*
21	12 50·6	142·8	3	59·0	− 2·3	43·4	*h*
May 12	10 50·8	174·1	3	57·9	− 3·4	44·9	*i*
24	9 50·7	196·4	2	64·9	+ 3·6	47·9	*j*
30	9 11·0	201·8	0·5	58·5	− 2·8	43·9	*k*

Description.—(*a*) vS, F, chiefly on south band of the double belt. (*b*) vS, vF. (*c*) vS, F. (*d*) vS, mD. (*e*) Def. confused, no description possible. (*f*) vS, mD, chiefly on south band. (*g*) vS, F. (*h*) vS, F. (*i*) Two eS, mD, spots lying N. and S. (*j*) vS, mD, much elong. N. and S. (*k*) eS, F, on south band only.

Mean period of rotation = $10^h\ 14^m\ 44^s{\cdot}8 \pm 0^s{\cdot}30$ (271 rotations). The observations are in very satisfactory agreement with the exception of those of March 22, 29, and April 1, and it is probable that even these apparently discordant observations were due to a temporary displacement of the spot. On two nights the spot was noted as being situated chiefly on the south band of the double belt, whilst on a third night it was only seen on this southernmost band. The descriptions on May 12 and 24 also agree well, poor definition on the latter night not having allowed the spot to be seen double.

Dark Spot VI.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Apr. 1	11 47·0	128·1	1	11 47·0	− 0·9	10 14 45·2	*a*
18	13 35 6	154·7	2	48·9	+ 1·0	43·4	*b*
27	12 43·1	167·6	2	47·9	0·0	42·5	*c*

Description.—(*a*) No description possible, def. bad. (*b*) vS, F. (*c*) vS, F.

Mean period of rotation = $10^h\ 14^m\ 43^s{\cdot}4 \pm 0^s{\cdot}47$ (61 rotations). Observations very accordant.

Dark Spot VII.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 17	13 38·2	120·0	2	13 40·9	− 3·5	10 14 45·9	*a*
23	(12 52·5)	122·5	1	(30·0)	(−14·4)	...	*b*
Apr. 21	13 46·4	175·6	3	46 4	+ 2·0	43·2	*c*
27	13 11·6	184·3	3	46·0	+ 1·6	43·1	*d*
May 21	10 54·2	219·4	0·5	44·8	+ 0·4	42·5	*e*
30	10 2·8	232·2	2	43·9	− 0·5	42·2	*f*

Description.—(*a*) vS, mD. (*b*) No description possible, def. bad. (*c*) S, F. (*d*) S, F. (*e*) Inconspicuous, but def. bad. (*f*) S, F.

Mean period of rotation = $10^h\ 14^m\ 43^s{\cdot}5 \pm 0^s{\cdot}42$ (173 rotations). The observations are very accordant with the exception of that of March 23, which was made under very unfavourable circumstances. On three nights the spot was recorded as S. on the scale of size, which is unusually large for a spot on *Saturn*.

Dark Spot VIII.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 18	16 32·5	90·1	0·5	11 42·8	− 2·7	10 14 53·0	*a*
Mar. 2	15 36·3	115·8	3	54·8	+ 9·3	48·7	*b*
Apr. 10	11 46·2	171·5	1	46·2	+ 0·7	42·9	*c*
May 1	9 42·6	201·0	1	40·7	− 4·8	42·0	*d*
4	9 28·0	207·0	0·5	42 9	− 2·6	43·6	*e*
10	(8 52·5)	215·1	...	(40·7)	(− 4·8)	...	*f*

Description.—(*a*) vS, F. (*b*) vS, F. (*c*) vS, mD. (*d*) S, mD. (*e*) S, F. (*f*) Very rough, spot a long way past transit when observed.

Mean period of rotation = $10^h\ 14^m\ 46^s{\cdot}5 \pm 1^s{\cdot}18$ (175 rotations).

Dark Spot IX.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 29	14 6·0	195·0	0·5	12 23·5	+ 0·6	10 15 51·8	*a*
Apr. 2	10 33·0	209·6	2	29·5	+ 6·6	47·8	*b*
28	12 19·6	278·6	3	19·6	− 3·3	40·4	*c*
May 4	11 54·2	292·7	1	14·4	− 8·5	30·1	*d*
7	11 57·1	308·9	1·5	27·4	+ 4·5	51·4	*e*
June 1	(7 0)	14·5	...	(17·8)	(− 5·1)	...	*f*

Description.—(*a*) Probably vS, F, but def. bad. (*b*) Two eS, mD, rather well def. spots. (*c*) Two eS, mD, rather well def. spots. (*d*) vS, F, rather well defined. (*e*) S, F. (*f*) Obs. by Brenner.

Mean period of rotation = $10^h\ 15^m\ 43^s{\cdot}7 \pm 2^s{\cdot}30$ (91 rotations). Observations not so accordant as usual. The descriptions on two nights, April 2 and 28, are identical and peculiar.

Dark Spot X.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Apr. 10	14 14·0	258·2	1	10 27·2	− 0·8	10 15 63·8	*a*
17	10 35·3	284·1	1	35·3	+ 7·3	51·9	*b*
28	13 13·3	310·1	0·5	21·4	− 6·6	32·5	*c*

Description.—(*a*) vS, F. (*b*) S, mD. (*c*) Probably S, F.

Mean period of rotation = $10^h\ 15^m\ 52^s{\cdot}7 \pm 5^s{\cdot}46$ (42 rotations).

Dark Spot XI.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 18	17 54·1	138·0	2	16 54·9	+10·3	10 15 49·8	*a*
Mar. 2	17 5·3	168·0	3	45·4	+ 0·8	49·1	*b*
8	16 44·5	185·3	1·5	44·5	− 0·1	47·2	*c*
23	15 50·3	226·9	1	39 6	− 5·0	44 8	*d*
Apr. 1	15 20·3	253·3	0·5	39·1	− 5·5	42·5	*e*
2	11 56·9	258·8	2	44·1	− 0·5	49·1	*f*

Description.—(*a*) vS, F, susp. dup. (*b*) vS, F. (*c*) vS, mD, probably dup. (*d*) No description possible, def. bad. (*e*) Same as *d*. (*f*) vS, F.

Mean period of rotation = $10^h\ 15^m\ 48^s{\cdot}2 \pm 0^s{\cdot}59$ (100 rotations). The observations are in satisfactory agreement with the exception of the first.

In 1893 the dark northern spots formed two distinct classes or groups, according to the lengths of their periods of rotation. The same peculiarity presents itself with regard to the spots observed in 1894, with the difference that we have here three quite distinct groups.

	No.	Period of Rotation. h m s s	No. of Rotations.
Group A	I.	10 14 62·0 ± 1·38	236
	II.	10 14 58·7 ± 0·97	140
	III.	10 14 57·2 ± 0·57	215
	IV.	10 14 55·4 ± 0·73	210
Group B	V.	10 14 44·8 ± 0·30	271
	VI.	10 14 43·4 ± 0·47	61
	VII.	10 14 43·5 ± 0·42	173
	VIII.	10 14 46·5 ± 1·18	175
Group C	IX.	10 15 43·7 ± 2·30	91
	X.	10 15 52·7 ± 5·46	42
	XI.	10 15 48·2 ± 0·59	100

Combining the different results, the following are the final values for the three groups :

	h	m	s	s	
Group A. Mean Period of Rotation =	10	14	57·29	± 0·68	(4 spots)
„ B. „ „ „ =	10	14	44·23	± 0·30	(4 spots)
„ C. „ „ „ =	10	15	47·97	± 0·60	(3 spots).

The different results composing each group agree closely *inter se*, as they did in 1893, and the different groups are quite distinct from each other. Hence the surface material of *Saturn* must have rotated in 1894, as in 1893, at widely differing rates in the same north latitude, but at different parts of the planet. Taking the date 1894 April 20 as epoch, the spots of group A extend from longitude 30° to 130° ; those of group B from longitude 140° to 200° ; and those of group C from longitude 240° to 360°, all according to Mr. Marth's Ephemeris. The extent in latitude of the northern spot zone is approximately from 17° N. to 37° N. It is worth noting that the periods of the four spots of group A become progressively less and less. This peculiarity is perhaps due to the influence of the more swiftly moving group B, the spots IV. and V. having approached very near one another towards the end of the observations.

The three groups being of nearly equal importance, the average period of rotation for the whole northern spot zone in 1894 may be found by taking the mean of the periods of these three groups. For 1893 I have taken the mean of the two groups A and B of that year. The following is a comparison of the results :

	h	m	s	
1893 Mean Rot. Per. =	10	14	44·7	(10 spots)
1894 „ „ „ =	10	15	9·8	(11 spots),

the difference being + $25^{s}\cdot1$.

With respect to the identification of the spots of 1894 with those observed in 1893, it is not possible to do this with certainty as regards the individual spots on account of the long interval separating the two series of observations, and the great changes that have occurred. But it is otherwise with respect to certain of the *groups* of spots. Thus, group A of 1894 has very nearly the same rotation period as group B of 1893 ($10^{h}\ 14^{m}\ 57^{s}\cdot3$ compared with $10^{h}\ 15^{m}\ 0^{s}\cdot5$), and by calculating back the position of the former group, it appears that this group is in fact identical with the preceding part of group B, 1893, the spots which formed the following part of the last-named group having apparently disappeared.

Similarly group B of 1894 appears to be identical with group A of 1893, though there has been an increase in the period of rotation amounting to 15^{s}. Here also about half the spots of the last-named group seem to have disappeared.

The Bright Equatorial Spots.

The bright equatorial spots of 1894 were similar in appearance and position to those observed in 1893. Owing to the ring system being more open, they were perhaps rather better seen than they had been in the latter year. A narrow dark belt, approximately marking the planet's equator, was frequently observed to cut across the bright spots, dividing them into two parts.

Bright Spot 1.

Date.	T.	Long.	Weight.	T′.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 18	15 35·4	56·6	2	13 24·7	+ 0·4	10 13 6·8	*a*
Mar. 2	13 39·7	47·4	3	23·8	− 0·5	8·2	*b*
16	14 54·1	39·7	1	28·0	+ 3·7	7·8	*c*
25	13 30·2	34·4	0·5	30·2	+ 5·9	6·5	*d*
Apr. 18	9 29·5	10·3	1	18·7	− 5·6	1·7	*e*
May 16	11 54·7	350·8	1	20 3	− 4·0	4·7	*f*
June 1	(6 7·6)	343·7	...	(27·8)	(+ 3·5)	...	*g*

Description.—(*a*) vS, F. (*b*) vS, F. (*c*) vS, mB, yellowish. (*d*) Probably vS, mB. (*e*) vS, mB. (*f*) vS, F. (*g*) Obs. by Brenner.

Mean period of rotation = $10^h\ 13^m\ 6^s{\cdot}5 \pm 0^s{\cdot}63$ (204 rotations). The spot was rather a bright one.

Bright Spot 2.

Date.	T.	Long.	Weight.	T′.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 8	13 33·8	73·4	2	11 47·8	0·0	10 12 58·4	*a*
16	15 32·7	62·3	2	40·0	− 7·8	63·8	*b*
Apr. 9	11 52·6	50·4	3	52·6	+ 4·8	64·0	*c*
18	10 25·9	43·4	2	52·9	+ 5·1	67·7	*d*
21	9 49·9	36·8	1	45·8	− 2·0	59·2	*e*
June 1	(7 0)	14·5	...	(63·8)	(+16·0)	...	*f*

Description.—(*a*) S, F, seen plainly. (*b*) vS, F, well seen. (*c*) S, F, plain. (*d*) vS, F, plain. (*e*) vS, mB, creamy white. (*f*) Obs. by Brenner.

Mean period of rotation = $10^h\ 13^m\ 3^s{\cdot}1 \pm 1^s{\cdot}09$ (103 rotations). The spot was rather a plain one.

Bright Spot 3.

Date.	T.	Long.	Weight.	T′.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 18	17 33·7	126·0	2	15 36·4	0·0	10 13 0·7	*a*
Mar. 2	15 35·9	115·6	3	35·9	− 0·5	1·2	*b*
22	15 45·5	99·1	1·5	36·9	+ 0·5	1·9	*c*

Description.—(*a*) eS, F. (*b*) vS, F. (*c*) vS, F.

Mean period of rotation = $10^h\ 13^m\ 1^s{\cdot}2 \pm 0^s{\cdot}21$ (75 rotations). Observations very accordant.

Bright Spot 4.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 29	11 49·9	115·2	1	13 19·2	+ 1·0	10 12 40·6	*a*
Apr. 9	13 17·0	100·0	0·5	17·0	− 1·2	42·6	*b*
21	11 13·5	85·9	3	18·5	+ 0·3	44·8	*c*

Description.—(*a*) Probably mB. (*b*) eS, eF. (*c*) vS, vF.

Mean period of rotation = $10^h\ 12^m\ 43^s{\cdot}6 \pm 0^s{\cdot}84$ (54 rotations). Observations very accordant.

Bright Spot 5.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 2	16 58·0	163·7	3	11 37·6	− 4·1	10 12 41·9	*a*
26	12 47·5	134·3	0·5	43·5	+ 1·8	37·3	*b*
Apr. 1	11 41·3	124·8	1	41·3	− 0·4	37·9	*c*
18	12 8·6	103·7	2	45·4	+ 3·7	37·9	*d*
27	10 28·6	88·6	3	40·8	− 0·9	34·5	*e*
June 1	(7 52·4)	45·2	...	(48·9)	(+ 7·2)	...	*f*

Description.—(*a*) vS, F. (*b*) mL, mB. (*c*) No description possible, def. bad. (*d*) vS, F. (*e*) vS, mB, irregular on edges and ill def. with 320; well def. with 225. (*f*) Obs. by Brenner.

Mean period of rotation = $10^h\ 12^m\ 38^s{\cdot}1 \pm 0^s{\cdot}99$ (131 rotations). Spot rather a conspicuous one.

Bright Spot 6.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 8	16 50·0	188·5	1·5	9 24·2	− 0·4	10 12 40·6	*a*
26	13 41·1	165 7	3	26·6	+ 2·0	39·7	*b*
Apr. 19	9 27·0	133·7	1	27·0	+ 2·4	38·6	*c*
May 26	9 40·5	80·0	1	20·9	− 3·7	36·7	*d*
June 1	(8 44·5)	76·4	...	(28·4)	(+ 3·8)	...	*e*

Description.—(*a*) vS, F. (*b*) vS, F, plain. (*c*) Small and most difficult to see. It appeared only about 0″·5 in diam. Obs. by Brown. (*d*) S, eF, irregular on edges, yellowish. (*e*) Obs. by Brenner.

Mean period of rotation = $10^h\ 12^m\ 39^s{\cdot}3 \pm 0^s{\cdot}49$ (185 rotations). Observations in excellent agreement. The spot was observed by three observers.

Bright Spot 7.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 21	12 43·2	227·2	1	10 24·8	− 1·9	10 11 73·9	*a*
23	15 53·7	228·9	1	34·3	+ 7·6	54·8	*b*
26	15 5·5	215·2	1	20·7	− 6·0	91·6	*c*
29	14 36·3	212·8	1	26·1	− 0·6	81·5	*d*
Apr. 2	10 28·0	206·6	1	28·0	+ 1·3	80·8	*e*
10	12 18·3	190·4	4	26·4	− 0·3	75·0	*f*

Description.—(*a*) vS, mB, def. bad. (*b*) Probably mB, def. bad. (*c*) Inconspicuous, spot only glimpsed faintly, def. bad. (*d*) Inconspicuous, def. very bad. (*e*) S, F. (*f*) vS, mB, plain.

Mean period of rotation = $10^h\ 12^m\ 15^s{\cdot}8 \pm 2^s{\cdot}76$ (47 rotations). The first four observations were made under very unfavourable conditions, definition on each night being bad. Considering this circumstance, the observations are in good agreement.

Bright Spot 8.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 20	15 13·3	293·4	3	13 4·4	− 0·6	10 12 23·7	*a*
Apr. 27	13 5·6	180·8	3	5·6	+ 0·6	23·2	*b*
May 12	10 18·0	154·9	1	5·1	+ 0·1	23·1	*c*

Description.—(*a*) vS, mB, plain. (*b*) vS, F. (*c*) S, mB, unusually plain.

Mean period of rotation = $10^h\ 12^m\ 23^s{\cdot}4 \pm 0^s{\cdot}12$ (190 rotations). Observations very accordant.

Bright Spot 9.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 24	13 9·9	257·7	3	11 27·6	− 0·1	10 12 19·9	*a*
Apr. 2	11 27·5	241·5	0·5	27·5	− 0·2	20·0	*b*
May 1	9 23·5	189·8	1	28·0	+ 0·3	20·3	*c*

Description.—(*a*) vS, F. (*b*) vS, F. (*c*) Probably mB, def. bad.

Mean period of rotation = $10^h\ 12^m\ 20^s{\cdot}0 \pm 0^s{\cdot}08$ (89 rotations). Observations remarkably accordant.

Bright Spot 10.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 20	16 28·5	337·5	3	14 8·6	− 0·4	10 12 23·5	*a*
Mar. 4	14 8·9	314·3	0·5	3·3	− 5·7	26·0	*b*
Apr. 2	12 17·3	270·7	1	12·1	+ 3·1	24·2	*c*
10	14 6·0	253·6	0·5	6·0	− 3·0	25·2	*d*
May 4	9 48·8	219·2	3	15·8	+ 6·8	27·1	*e*
7	9 9·0	210·3	0·5	9·3	+ 0·3	25·1	*f*
24	9 23·9	180·7	1	7·6	− 1·4	22·7	*g*
June 13	(9 0·0)	141·9	0·5	(13 58·9)	(−10·1)	...	*h*

Description.—(*a*) vS, F, plain. (*b*) S, F, plain. (*c*) vS, vF ? def. bad. (*d*) vS, F. (*e*) vS, mB. (*f*) vS, vB, seen brightly. (*g*) vS, mB, white, well seen. (*h*) Probably vS, F, very rough obs.

Mean period of rotation = $10^h\ 12^m\ 24^s{\cdot}9 \pm 0^s{\cdot}46$ (218 rotations). A plain spot.

Bright Spot 11.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 3	16 31·5	16·0	0·5	9 43·7	− 4·7	10 12 27·8	*a*
Apr. 17	9 46·1	255·2	3	46·1	− 2·3	25·7	*b*
May 7	9 38·6	227·7	3	56·5	+ 8·1	25·2	*c*
June 13	9 31·0	160·1	2	47·3	− 1·1	23·3	*d*

Description.—(*a*) S, mB, plain. (*b*) vS, mB. (*c*) vS, F. (*d*) vS, mB, well def., plain.

Mean period of rotation = $10^h\ 12^m\ 25^s{\cdot}1 \pm 0^s{\cdot}45$ (305 rotations). A bright spot.

Bright Spot 12.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 16	12 54·2	329·3	2	9 26·6	+ 6·2	10 12 19·9	*a*
May 10	9 17·5	229·7	0·5	17·5	− 2·9	25 7	*b*
12	12 17·3	224·9	2	15·4	− 5·0	28·3	*c*
24	10 11·2	208·4	1	22·3	+ 1·9	30·7	*d*

Description.—(*a*) vS, F, yellowish. (*b*) vS, mB. (*c*) vS, F. (*d*) vS, vF.

Mean period of rotation = $10^h\ 12^m\ 23^s{\cdot}5 \pm 1^s{\cdot}72$ (162 rotations).

Bright Spot 13.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Feb. 3	17 39·7	56·0	1	10 41·9	− 2·3	10 12 22·6	*a*
20	17 56·5	29·2	0·5	47·2	+ 3·0	19·7	*b*
Mar. 4	15 33·9	4·2	0·5	40·4	− 3·8	21·6	*c*
21	15 44·5	334·2	0·5	40·4	− 3·8	23·2	*d*
Apr. 17	10 37·0	285·1	1	37·0	− 7·2	22·5	*e*
28	12 12 8	274·6	3	52·6	+ 8·4	23·5	*f*
May 1	11 41·0	270·5	1	54·3	+ 10·1	23·4	*g*
7	10 19·0	251·4	1	39·6	− 4·6	21·7	*h*
10	9 54·2	251·3	4	48·3	+ 4·1	23 7	*i*
30	9 27·5	211·5	4	40·5	− 3·7	17 0	*j*

Description.—(*a*) vS, vF. (*b*) vS, vF. (*c*) No description possible, def. bad. (*d*) Same as *c*. (*e*) vS, F, plain. (*f*) S, F, irregular on edges, plain.

(*g*) No description possible, def. bad. (*h*) vS, vF. (*i*) eS, F, fading off and irregular on the edges. (*j*) vS, mB, fading off on edges.

Mean period of rotation = $10^h\ 12^m\ 21^s{\cdot}6 \pm 0^s{\cdot}61$ (272 rotations). The observations are rather discordant, but this is due chiefly to the fact that the motion of the spot was evidently not uniform. The spot appears to have rotated rather more swiftly than would accord with the above period between February 3 and April 17. There then occurred a sudden shift to the east, producing between April 17 and 28 a difference of over a quarter of an hour in the time of transit, whilst subsequently to the latter date the former more rapid motion of the spot was resumed. The nature of the change closely resembles that which occurred in the case of spot No. 1 of 1893.* On three nights the spot was particularly noted as fading off on the edges, whilst on two nights it was seen to be irregular on the edges.

Bright Spot 14.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
May 4	11 35·5	281·8	0·5	10 30·1	+ 0·1	10 12 29·1	*a*
10	10 29·8	272·2	2	29·8	− 0·2	29·2	*b*
June 25	9 1·4	199·5	0·5	30·2	+ 0·2	29·3	*c*

Description.—(*a*) vS, vF. (*b*) vS, F. (*c*) vS, mB.

Mean period of rotation = $10^h\ 12^m\ 29^s{\cdot}2 \pm 0^s{\cdot}03$ (122 rotations). Observations very accordant.

Bright Spot 15.

Date.	T.	Long.	Weight.	T'.	Diff.	Period of Rotation.	
	h m	°		h m	m	h m s	
Mar. 22	13 23·9	16·1	3	11 50·2	+ 0·2	10 12 31·6	*a*
Apr. 9	10 8·5	349·4	0·5	51·9	+ 1·9	31·1	*b*
May 7	11 53·0	306·5	2	53·0	+ 3·0	30·2	*c*
June 25	9 46·4	225·9	0·5	44 8	− 5·2	28·1	*d*

Description.—(*a*) vS, F. (*b*) vS, vF. (*c*) vS, F. (*d*) vS, F.

Mean period of rotation = $10^h\ 12^m\ 30^s{\cdot}8 \pm 0^s{\cdot}40$ (223 rotations).

The foregoing bright equatorial spots fall into three distinct groups or classes, as under :

	No.	Period of Rotation.	No. of Rotations.
		h m s s	
Group *a*	1	10 13 6·5 ± 0·63	204
	2	10 13 3·1 ± 1·09	103
	3	10 13 1·2 ± 0·21	75

* See *Monthly Notices*, vol. liv. p. 310.

	No.	Period of Rotation. h m s s	No. of Rotations.
Group *b*	4	10 12 43·6 ± 0·84	54
	5	10 12 38·1 ± 0·99	131
	6	10 12 39·3 ± 0·49	185
Group *c*	7	10 12 15·8 ± 2·76	47
	8	10 12 23·4 ± 0·12	190
	9	10 12 20·0 ± 0·08	89
	10	10 12 24·9 ± 0·46	218
	11	10 12 25·1 ± 0·45	305
	12	10 12 23·5 ± 1·72	162
	13	10 12 21·6 ± 0·61	272
	14	10 12 29·2 ± 0·03	122
	15	10 12 30·8 ± 0·40	223

The following are the mean values for the three groups :

	h	m	s	s	
Group *a*. Mean Period of Rotation =	10	13	1·69	± 0·70	(3 spots)
„ *b*. „ „ „ =	10	12	40·03	± 0·91	(3 spots)
„ *c*. „ „ „ =	10	12	25·83	± 0·86	(9 spots).

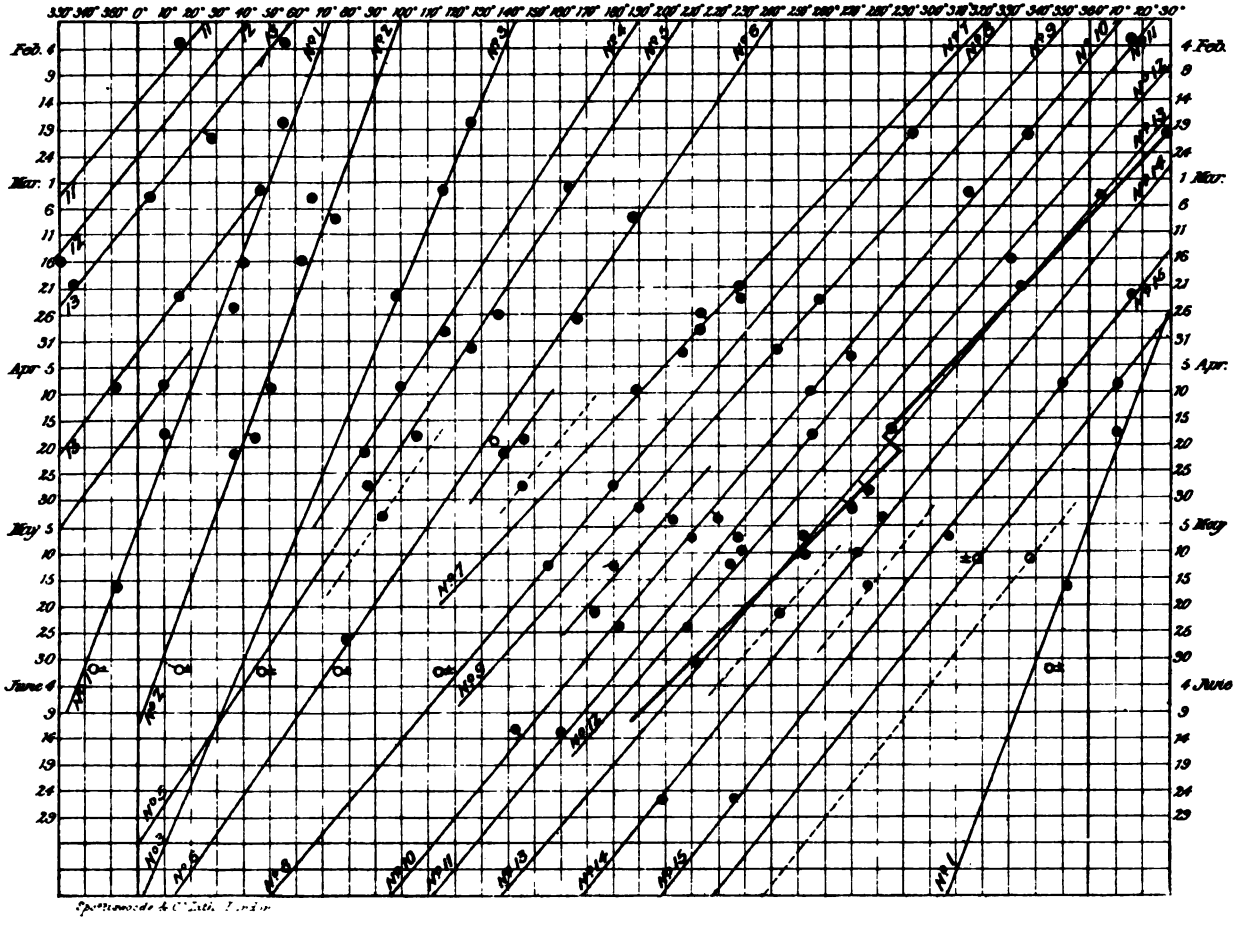
These three groups are all quite distinct from one another. The two last spots of group *c*, Nos. 14 and 15, would appear to form a sub-group, differing somewhat from the remaining spots of this group. For the date 1894 April 20 the spots of group *a* extend from longitude 0° to 80° ; those of group *b* from longitude 80° to 160° ; and those of group *c* from longitude 160° to 360°. The limits of latitude of the equatorial spot zone are approximately 6° N. and 6° S.

In order to find the average period of rotation for the whole spot zone I have taken the mean of the results for these three groups, giving group *c* treble weight. The like result for 1893 has been got by taking the simple mean of group C and spot No. 4 of that year. The following then are the average rotation periods of the whole equatorial spot zone in the different years, the values for 1891 and 1892 being the approximate ones found by Mr. Marth.

	h	m	s	s	
1891 Mean Period of Rotation =	10	14	21·8		Diff. = 43·6
1892 „ „ „ =	10	13	38·2		Diff. = 45·8
1893 „ „ „ =	10	12	52·4		Diff. = 16·6
1894 „ „ „ =	10	12	35·8		

It would appear from the above figures that the rate of decrease in the length of the period is diminishing. Between 1891 and 1894 the decrease amounts to $1^m\ 46^s$. This difference means a very considerable increase in the velocity of motion of

SATURN — *Spot Chart for the Bright Equatorial Spots of 1894*



the surface material, amounting to 66 miles per hour. In other words, the great equatorial atmospheric current of *Saturn* was blowing 66 miles an hour more quickly in 1894 than it was in 1891.

As in the case of the dark northern spots, it does not seem possible to certainly identify any individual bright spot with those observed in 1893, though it is otherwise as regards the groups. Group *a* of 1894 has nearly the same period as group C of 1893 ($10^h\ 13^m\ 1^s{\cdot}7$ compared with $10^h\ 12^m\ 59^s{\cdot}4$), and by calculating back its position, it appears that the former group is identical with the preceding portion of group C, 1893. The spots which formed the remaining part of the last-mentioned group (including amongst them the spots 1, 2, 3, and 5) had disappeared in 1894.

Group *b* of 1894 is also evidently identical with the region represented by spot 4 of the preceding year. It is even probable that spot 6 of 1894 is the same as spot 4 of 1893, a slight decrease having occurred in the length of its period in the interval. The position of the former spot calculated back to the early part of 1893 June agrees exactly with that of the latter.

The diagram, Plate 7, contains all the observations of the bright equatorial spots which have come to my knowledge, my own observations being represented by dots, and those of other observers by circles. In work of this kind everything, of course, depends upon the correct identification of the different spots. It will be seen from the diagram that the identifications are on the whole very satisfactory. Thus, in the cases of spots 3, 4, 5, 6, 8, 9, 14, and 15, the dots representing the observations are almost, where not actually threaded by the straight lines, drawn through the observations of each spot, whilst in no case do the discordances appear large enough to render the identifications doubtful. The observations are perhaps most discordant in the case of spot 13, but on the hypothesis that a sudden shift occurred in the position of this spot between April 17 and 28, they also come into very satisfactory agreement. This state of things has been indicated in the diagram by thick lines.

Micrometrical Measures of the Ball and Ring System of the Planet Saturn, and Measures of the Diameter of his Satellite Titan. Made with the 36-inch Equatorial of the Lick Observatory. By E. E. Barnard, A.M., Dr. Science.

From the decided advantage in the large scale of our great telescope, it would seem very important that a careful redetermination of the dimensions of the Saturnian Ball and Ring system should be made with it.

Recognising this, I have been anxious to do the work, and have taken advantage of the first opportunity that has occurred: this was the opposition of 1894.

The measures of the planet were taken up in February and carried through until July.

During these observations I sought to measure everything that could be seen about the ball and rings.

The measures have been made with the greatest possible care, and will, I think, represent the best results attainable in this direction with the 36-inch refractor.

The observations confirm the previous measures of this planet, and are specially consistent with the excellent work of Professor Hall, with the 26-inch at Washington, in the years 1884 to 1887.

They show essentially that no change has taken place in the Saturnian System since the first systematic measures were made of it. They also thoroughly prove (as did the measures of Hall) the fallacy of the supposition that the rings are sensibly closing in on the planet.

One important question that I wished to settle in these measures was that of a possible eccentricity of the rings with reference to the ball. It had been previously reported that the ball is not exactly in the centre of the rings.

To determine whether this is true, I made a series of measures of the distance from the ends of the ring to the preceding and following limbs of the planet. The outer edges of the ring were selected because they appeared to be more definite than the inner edge of the inner bright ring. A couple of nights, however, were devoted to measures of this last quantity, with the result of verifying the other measures.

It will be seen that these systematic measures do not show any sensible deviation of the ball from the exact centre of the rings during the opposition of 1894. Hence, if any eccentricity exists it must lie nearly in the line of sight, and cannot therefore be detected with a micrometer.

I also made a set of measures of the distance from the centre of the preceding and following parts of the Cassini division to the nearest limbs of the planet.

It will be seen that the measures of this quantity are accordant, and that each one persistently indicates that this division is eccentric to the ball. The means of these measures would place the ball $0''{\cdot}25$ towards the preceding portion of the division. (See "Note" at the close of this paper.)

Though the observations are consistent in pointing to this, I do not think it can be accepted as proved that the difference is real. To definitely settle this question I shall make a special series of measures during the coming opposition of *Saturn*.

Physical appearance of Saturn.

The physical appearance of the planet throughout the measures was quite normal.

The black and white spots lately seen upon *Saturn* by various little telescopes were totally beyond the reach of the

36-inch—as well as of the 12-inch—under either good or bad conditions of seeing. One narrow dusky belt alone was visible upon the ball. This was placed near the middle of a broad light equatorial zone, and just north of the trace of the rings.

The light zone was bordered to the north by a rather heavy dusky diffusion extending to the north limb. The southern edge of this—where it met the light zone—was of a warm colour, and gradually diffused into a colder or ashy-hued region that formed the true polar cap, and which was almost definitely bounded at its southern edge. Once or twice a very small and very dark spot was seen *at the North Pole.*

The Crape ring has appeared uniformly even in shade at the two ansæ. It was of a steely blue colour, and was not strongly contrasted with the sky. No markings whatever were seen upon it. The inner edge was a uniform curve; the serrated or saw-toothed appearance of its inner edge, which had previously been seen with some small telescopes, was also beyond the reach of the 36-inch.

No division was seen between the Crape ring and the inner bright ring, as has sometimes been shown on drawings. This supposed division, however, was proved to have no real existence by my observations of the eclipse of *Japetus* in the shadows of the rings 1889 November 1.

There is no distinct junction between the two rings, though the bright ring is not well defined where it meets the Crape ring. It looks as if there was a very quick diffusion of the inner bright ring into the dusky ring, as if, indeed, the latter were formed at the expense of the bright ring. This peculiarity was also shown to exist by the observations of the eclipse of *Japetus* mentioned. In examining the trace of the Crape ring on the ball one readily sees that the ring is very thin at its inner edge, and that it grows much denser where it joins the bright ring. This increasing density of the Crape ring towards the bright ring was first beautifully shown to be a fact by the observed light curve at the eclipse of *Japetus* in 1889 (see *M.N.* 1890 January, vol. L.).

In the present observations the ball could faintly be seen through a small portion of the projection of the Crape ring, but not up to the bright ring. This trace was, on account of the bright ball behind it, sensibly lighter than where the ring was projected against the dark sky.

The inner portion of the inner bright ring is exactly the same depth of shade as the outer ring. About $\frac{1}{4}$ of its outer edge, next the Cassini division, however, is very bright. Indeed, this portion of the inner ring is brighter than any other part of the ball or rings.

From the southern declination of the planet one or two features previously seen were not readily made out. The division in the outer ring seen by Professor Keeler in 1888 was not visible at any time, though I had seen it in 1889.

The Encke "division" was not seen at the time of my

drawing, though I have seen it before. By the way, I do not think this marking is a real division like that of Cassini. It has always appeared to me to be a rather feeble dark line *on* the ring. But, as I understand, it has been seen on both the south and north faces of the ring. It must therefore penetrate through the ring. It would seem probable that at this point in the rings all the particles for some reason have not been removed, as appears to have occurred in the case of the Cassini division; the "division" would therefore be only partly free of them, or in a similar condition to the Crape ring.

I have made a careful drawing (Plate 8) of the appearance of the planet and his rings during the measures, and have shown only what I have seen with certainty. It is true the picture appears abnormally devoid of details when compared with drawings made with some of the smaller telescopes. I am satisfied, however, to let it remain so.

On several occasions *Saturn* was examined after sunrise or before sunset. Under these conditions, when the air was steady, the details were perhaps better seen than on a dark sky. They were also considerably better seen by using a very small hole in a cap over the eye-piece. The hole that gave the best results was about 0·03 or 0·04 inch in diameter. When the object is bright this always steadies the image by reducing the quantity of light, and hence the effect of atmospheric tremors.

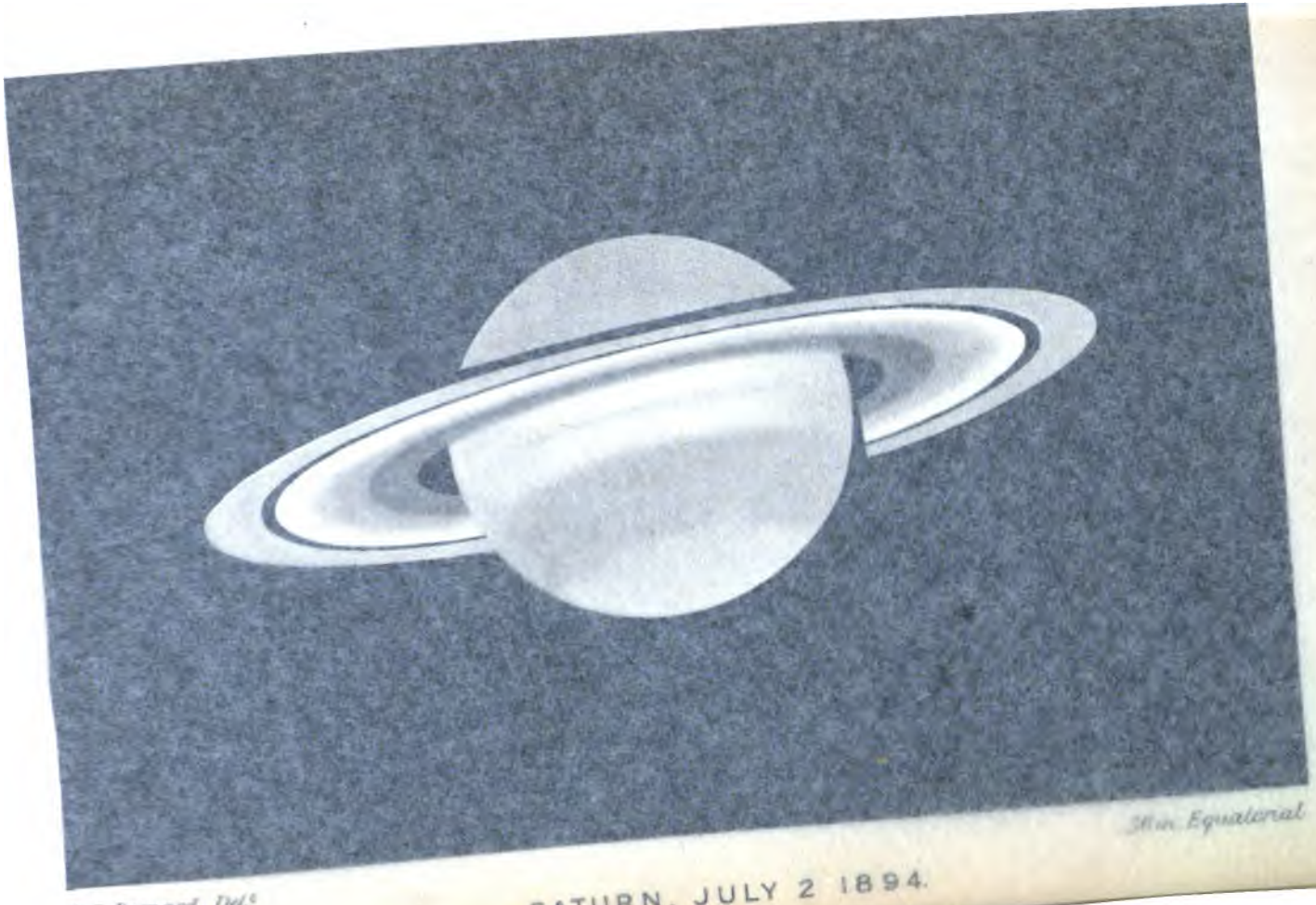
This is also a very useful device for measuring very close double stars with high powers, as it gives neater discs and cuts out a great deal of stray light, at the same time that it makes the micrometer wires sharper. It might be supposed that this is the simple equivalent of placing a diaphragm over the object-glass. This, however, is not so.

Cutting down the aperture of the objective not only reduces the quantity of light, and thus the apparent effect of atmospheric tremors, but it also diminishes the separating power of the objective, and is therefore for many purposes an objectionable method. Diminishing the size of the beam that enters the eye from the eye-piece does not affect the separating power of the object-glass, at the same time that it reduces the amount of light and sharpens the image.

This, indeed, is very fortunate, because it is quite a difficult thing to get at and to diaphragm down the object-glass of a great telescope. There is a series of these small eye-caps here for use with the 36-inch. They can be slipped off and changed in a couple of seconds. Mr. Burnham had these caps made, and always used them in his double-star work.

I have also often examined the planet with the 12-inch, but the view was far finer through the 36-inch, and the details better seen when the air was good.

I also tried diaphragms on the 12-inch—cutting it down as small as 6 inches. Though this steadied the image somewhat, it did not reveal anything not seen with the full aperture.



36 in. Equatorial

SATURN, JULY 2 1894.

E. E. Barnard. Del.

...ver, though I have seen it before. By the way, I do not ...the dark marking is a real division like that of Cassini. It has ...ways appeared to me to be a rather feeble dark line *on* the ...ring. But, as I understand, it has been seen on both the south ...and north ...s of the ring. It must therefore penetrate through ...the ring. It would seem probable that at this point in the rings ...all the particles for some reason have not been removed, as ...appears to have occurred in the case of the Cassini division; ...the "division" would therefore be only partly free of them, or ...in a similar condition to the Crape ring.

I have made ...careful drawi... (Plate 8) of the appearance of ...the planet and ...his rings duri... measures, and have shown only ...what I have ... with ce... It is true the picture appears ...abnormally ...evoid of de... ...n compared with drawings made ...with ...one of ...the small ...epes. I am satisfied, however, ...to be ... so.

... was examined after sunrise or ...conditions, when the air was steady, ...r seen than on a dark sky. They ...r seen by using a very small hole in ...The hole that gave the best results ...inch in diameter. When the object is ...this ...ges the image by reducing the quantity ...and ...fect of atmospheric tremors.

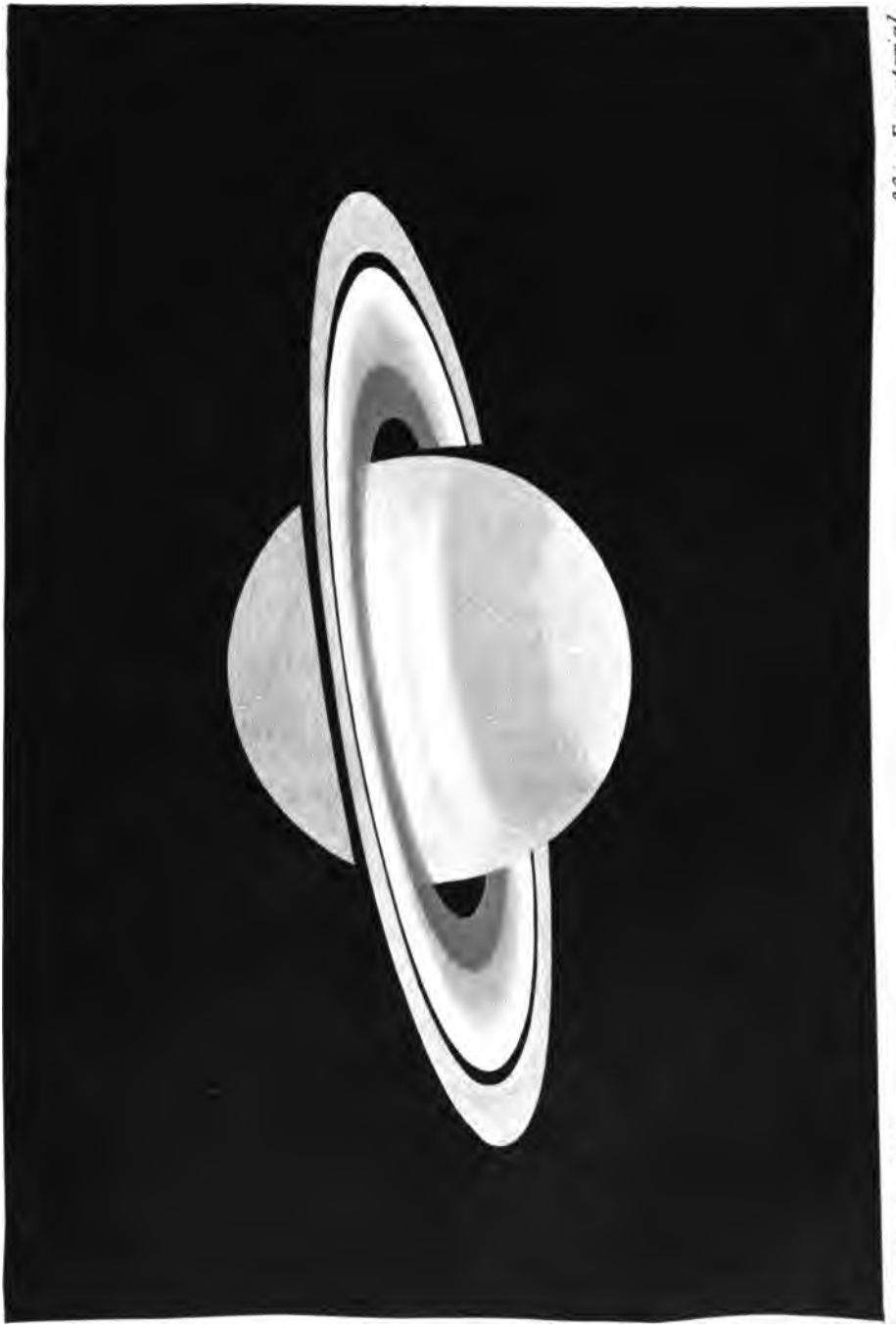
...his is ...very useful device for measuring very close ...double stars ...high pow... as it gives neater discs and cuts ...out a great ...ot stray l... at the same time that it makes ...the micrometer wires sha... It might be supposed that this ...is the ...equivalent of ...cing a diaphragm over the object ...glass ...s, however ... so.

...Stopping down th... ...re of the objective not only reduces ...the ... of ... thus the apparent effect of atmo... ...diminishes the separating power of ...for many purposes an objection... ...of the beam that enters the ...affect the separating power of ...that it reduces the amount of ...

I ..., because it is quite a difficult ...thing to ... down the object-glass of a ...great te... ... of these small eye-caps here ...for use w... the ... be slipped off and changed ...in a co... of s... ...ven had these caps made, and ...always used them ... work.

I have also ... planet with the 12 inch, but ...the view was far ... ...y 6 inch, and the details better ...when the air was ...

I also tried diaphr... ... 12 inch—cutting it down as ...all as 6 inches. Though ... steadied the image somewhat, ...it did not reveal anything ... seen with the full aperture.



36in. Equatorial

SATURN JULY 2 1894

E.E. Barnard Del.

Under good conditions, with the 36-inch, the Cassini division was easily traceable all round the ring, and apparently perfectly black and uniform, without any notches in it.

The shadow of the ball on the rings was uniform in outline, and did not show any difference of level in any of the rings. In a drawing of *Saturn* by Trouvelot in Newcomb's excellent *Popular Astronomy*, the brightest part of the inner bright ring is shown to project into the shadow of the ball, as if that part were at a higher level than the rest of the ring. I think this appearance has been an illusion due to the greater brightness of that part of the ring which by irradiation might cause it to seem to project into the shadow.

An original pastel drawing by Trouvelot, showing nearly the same phase of the rings as that of 1894, belongs to the Lick Observatory. It also shows this apparent projection. This very beautiful picture shows the rings faintly visible in the shadow of *Saturn*. This shadow has always appeared perfectly opaque to me in all telescopes.

In this drawing, from which the engraving in Newcomb's *Popular Astronomy* seems to have been made, Trouvelot has very beautifully shown the present appearance of the bright ring and the Crape ring where they join—very exactly like that observed in the great telescope. The picture in Newcomb's *Popular Astronomy*, however, does not properly represent the telescopic appearance, as the bright ring and Crape ring so gradually merge into each other that no one can tell where one begins or the other leaves off.

In my drawing I have not shown the junction between these two rings any more definite than it appears in the 36-inch. The consistency of my measures of the width of the Crape ring at the two ansæ alone shows that its outer edge, or the inner edge of the bright ring, was fairly definite.

One of the most beautiful and delicate drawings that I have seen of the planet *Saturn* was made, 1886 March 1, by Professor George Davidson, with his 6·4-inch Clark equatorial refractor at San Francisco.

Unfortunately this handsome picture has never been properly reproduced. Professor Davidson has spent a great deal of time and money in endeavours to properly place it before the astronomical world, but from its great delicacy he has not yet been able to do so. Professor Davidson's keen eyesight and well-known accuracy have shown in this picture essentially about as much as can be seen in the largest telescopes. One great thing which must commend itself to every observer familiar with *Saturn* in a telescope is that he has not shown a single abnormal feature.

Micrometrical Measurements.

Equatorial Diameter of Saturn.

1894.	Observed.	MΔ.	δ.
Mar. 25	19″21	17″58	+0″16
Apr. 9	19·50	17·77	−0·03
16	19·52	17·80	−0·06
23	19·33	17·67	+0·07
29	19·44	17·83	−0·09
30	19·29	17·70	+0·04
May 7	19·30	17·81	−0·07
21	19·10	17·89	−0·15
28	18·73	17·71	+0·03
June 11	18·40	17·77	−0·03
18	18·18	17·76	−0·02
25	17·85	17·64	+0·10
		17·744 ± 0·017	

These have been corrected for phase by the aid of Marth's Ephemeris.

The adopted mean distance of *Saturn* from the Sun to which these measures are reduced

$$= M\Delta = 9{\cdot}538861.$$

δ is the deviation from the mean.

Polar Diameter of Saturn.

1894.	Measured Diameter.	MΔ.	Corrected MΔ.	δ.
Mar. 25	17″80	16′29	16″20	+0″11
Apr. 9	17·97	16·38	16·29	+0·02
16	18·02	16·43	16·34	−0·03
23	17·88	16·34	16·26	+0·05
29	17·83	16·35	16·27	+0·04
30	17·80	16·33	16·25	+0·06
May 7	17·84	16·46	16·38	−0·07
21	17·36	16·26	16·18	+0·13
28	17·57	16·61	16·53	−0·23
June 11	16·88	16·30	16·23	+0·08
18	16·90	16·51	16·44	−0·13
25	16·57	16·38	16·31	0·00
			16·307 ± 0·020	

The second column contains the observations reduced to the mean distance from the Sun. The third contains this quantity

corrected for the inclination of the axis towards us. This is the true polar diameter.

Outer Diameter of Outer Ring.

1894.	Measured Diameter.	MΔ.	δ.
May 6	43″·93	40″·50	−0″·21
7	43·52	40·15	+0·13
21	42·98	40·26	+0·02
28	42·72	40·38	+0·09
June 11	41·72	40·28	0·00
18	41·01	40·06	+0·22
25	40·87	40·39	−0·10
July 2	39·91	40·26	+0·02
		40″·285 ± 0″·034	

Outer Edge of Outer Ring and Nearest Limb of Planet.

	Preceding.			*Following.*		
1894.	Measures.	MΔ.	δ.	Measures.	MΔ	δ
Feb. 25	11″·95	11″·23	−0″·03	12″·05	11″·33	−0″·05
26	11·96	11·24	−0·04	11·75	10·89	+0·38
Mar. 11	11·89	11·02	+0·18	12·08	11·19	+0·08
12	12·10	11·17	+0·03	11·92	11·00	+0·27
25	12·45	11·39	−0·19	12·30	11·26	+0·01
Apr. 9	12·36	11·27	−0·07	12·60	11·49	−0·21
16	12·23	11·15	+0·05	12·61	11·50	−0·22
23	12·26	11·21	−0·01	12·46	11·39	−0·11
29	12·16	11·15	+0·05	12·39	11·36	−0·08
May 6	12·28	11·32	−0·12	12·04	11·10	+0·17
21	11·83	11·08	+0·12	12·29	11·51	−0·23
		11″·203			11″·275	

Adding these to the measured equatorial diameter makes the outer diameter of the rings

$$= 40''\cdot222.$$

Diameter, Middle of Cassini's Division.

1894	Measured.	MΔ.	δ.
May 6	37″·48	34″·55	−0″·21
7	37·22	34·34	0·00
21	36·50	34·19	+0·15
28	36·09	34·12	+0·22
June 11	35·58	34·35	−0·01
18	35·24	34·42	−0·08
25	34·80	34·39	−0·05
		34″·337 ± 0″·037	

With this value and the measured width of the division (0″·558) we get for the inner diameter of the outer ring

34″·895;

and outer diameter of the inner bright ring

33″·779.

Inner Edge of Inner Bright Ring to Ball.

	Preceding.		Following.	
	Measured.	M∆.	Measured.	M∆.
1894.	″	″	″	″
Apr. 23	4·23	3·87	4·13	3·78
May 6	4·14	3·82	4·18	3·85
		3·845		3·815

Added to the measured equatorial diameter these will also give the following value of the inner diameter of inner bright ring.

25″·404.

Width of Cassini's Division.

	Measured.	M∆.	δ.
1894.	″	″	″
Apr. 23	0·59	0·55	+0·01
29	0·69	0·64	−0·08
30	0·67	0·63	−0·07
May 7	0·34	0·31	+0·25
21	0·35	0·32	+0·24
June 11	0·64	0·62	−0·06
18	0·62	0·61	−0·05
25	0·66	0·65	−0·09
July 1	0·49	0·49	+0·07
2		0·57	−0·01
		0·558	

The two measures in May are abnormally small. I have, however, retained them, but have given them only half weight.

In the first five measures the wires were placed so that their outer edges were tangent with the edges of the division; to these I have added 0″·13, the thickness of a micrometer thread. In the rest of the observations the edges of the division were bisected by the middle of the wires.

I have deduced the following values of the width of the Cassini division from previous measures of the rings.

Width of Cassini Division.

Herschel	1792	0″·645
F. Struve	1829	0·407
Bessel	1835	0·402
Decuppis and de Vico ...	1838	0·384
Encke	1838	0·775
O. Struve	1852	0·445
Jacob	1856	0·486
De La Rue	1856	0·940
W. C. Bond	1857	0·455
Hall	1884-7	0·420
	Mean	0·536

which is in close agreement with my own measures.

Centre Cassini's Division to Ball.

	Preceding.			Following.		
	Measured.	MΔ.	δ.	Measured.	MΔ.	δ.
1894.						
Apr. 23	8″·98	8″·21	−0″·09	9″·13	8″·35	+0″·02
30	8·91	8·18	−0·06	9·09	8·34	+0·03
May 7	8·65	7·98	+0·14	9·11	8·41	−0·04
		8·123			8·367	

By adding these to the measured equatorial diameter, we also get for the diameter of Cassini's division

34″·234.

Inner Diameter of Inner Bright Ring.

	Measured.	MΔ.	δ.
1894.			
May 7	28″·11	25″·94	−0″·39
21	27·16	25·44	+0·10
28	26·79	25·33	+0·21
June 11	26·36	25·45	+0·09
18	26·20	25·59	−0·04
25	25·82	25·52	+0·02
		25·545	

Width of Crape Ring.

		Preceding. Measured.	Mᴀ.	δ.	Measured.	Following. Mᴀ.	δ.
		"	"	"	"	"	"
Apr.	23	2·42	2·21	+0·06	...	...	...
	30	...	...	...	2·48	2 28	−0·06
May	6	2·48	2·29	−0 02	2·51	2·31	−0·09
	7	2·54	2·34	−0·07	2·46	2·27	−0·05
	21	2·29	2·14	+0·13	2·10	2·00	+0·21
June	18	2·34	2·29	−0·02	...	...	...
	25	2·25	2·22	+0·05	...	...	...
July	2	2·41	2·43	−0·16	...	...	...
			2·274			2·215	

Subtracting these values from the measured diameter of the inner bright ring, we get for the inner diameter of the Crape ring

21″·056

In the foregoing measures refraction corrections have been applied when appreciable.

Results of the Measures.

Collecting these results, we have the following values of the Saturnian Ball and Ring system from the measures of 1894 with the 36-inch refractor, reduced to the mean distance of *Saturn* from the Sun.

Equatorial Diameter of Saturn	...	...	17″·744
Polar Diameter of Saturn ...	...	...	16·307
Outer Diameter of Outer Ring	...	...	40·249
Inner Diameter of Outer Ring	...	...	34·864
Centre of Cassini Division ...	...	...	34·306
Outer Diameter of Inner Ring	...	...	33·748
Inner Diameter of Inner Ring	...	...	25·522
Inner Diameter of Crape Ring	...	...	21·033*
Width of Cassini Division ...	...	...	0·558

In this collection I have adopted the means of the different determinations of several of the quantities, giving weight according to the number of determinations.

To those who would like to see how these measured dimensions of *Saturn* and his rings appear in English miles, the following tabulation will be of interest. These dimensions rest upon the solar parallax derived by Professor Harkness.

From the Observations with the 36-inch.

Equatorial Diameter of Saturn	...	...	...	= 76,150 miles.
Polar Diameter of Saturn...	...	...	..	= 69,980 „
Outer Diameter of Rings ...	...	...	...	= 172,730 „
Inner Diameter of Outer Ring	...	...	...	= 149,620 „
Outer Diameter of Inner Ring	...	...	...	= 144,830 „
Inner Diameter of Inner Ring	...	...	...	= 109,530 „
Inner Diameter of Crape Ring	...	...	...	= 90,260 „ *
Width of Cassini Division	...	...	...	= 2,395 ,

Ellipticity of the Disc of Saturn.

From the equatorial and polar measures we have for the compression or ellipticity of the disc of *Saturn*—

$$\frac{E-P}{E} = \frac{1}{11{\cdot}44}.$$

Professor Hall's Measures.

For comparison with the measures I copy here the work of Professor Hall with the Washington 26-inch refractor from 1884 to 1887.

Equatorial Diameter of Saturn	...	...	...	17″·72 † (13 nights)
Polar Diameter of Saturn ...	...	...	...	...
Outer Diameter of Outer Ring	...	...	...	40·45 † (18 nights)
Inner Diameter of Outer Ring	...	...	...	34·95
Centre of Cassini Division ...	...	...	...	34·53 † (17 nights)
Outer Diameter of Inner Ring	...	...	...	34·11
Inner Diameter of Inner Ring	...	...	...	25·75 (5 nights)
Inner Diameter of Crape Ring	...	...	...	20·52 (2 nights)
Width of Cassini Division ...	...	...	...	0·42 (? nights)

Professor Hall does not give his measures of the width of the Cassini division. It is the difference between our measures of this quantity and the slight difference in the measures of the diameter of the Cassini division that produces the discrepancy in our results for the values of the inner diameter of the outer ring, and the outer diameter of the inner ring. Professor Hall did not measure the polar diameter.

* See "Note, 1895 April 1." That follows this paper, where a smaller diameter is got by direct measures. It should be preferred to the above value.

† The probable errors are respectively ±0″·030, ±0″·042, ±0″·025.

The results of these filar micrometer measures with two of the most powerful telescopes of to-day ought to be strictly comparable. It will be seen that they are in very good accord, as much so, indeed, as can be expected from two different instruments and two different observers in dealing with an object of this kind.

Here are the differences, Hall-Barnard :—

Equatorial Diameter	= −0″·02
Outer Diameter of Ring	= +0·20
Inner Diameter of Outer Ring	= +0·09
Centre of Cassini Division	= +0·22
Outer Diameter of Inner Ring	= +0·36
Inner Diameter of Inner Ring	= +0·23
Inner Diameter of Crape Ring	= −0·51
Width of Cassini Division	= −0·14
Mean Difference H−B	= +0 054

The magnifying power used in all the measures was 520. The image was seldom at all good with 1000. From 500 to 700 gave the best results, and often the view was better with 350.

Measures of the Diameter of Titan.

Some measures were also obtained of the diameter of *Titan*. It was seldom, however, that the disc of this satellite could be seen clear enough for measurement. Under such conditions measures would have been useless. The satellite was, therefore, attempted only when its disc could be clearly seen. The measures of this object were made with 1000 diameters, the same power used in my measures of the diameters of *Ceres*, *Pallas* and *Vesta*, and also for the measures of the four bright satellites of *Jupiter*.

I think these measures of *Titan* will be good.

Diameter of Titan.

	Measured.	MΔ.	δ.
1894 May 6	0″·53	0″·49	+0″·10
7	0·53	0·49	+0·10
June 18	0·62	0·61	−0·02
25	0·75*	0·74	−0·15
July 2	0·60	0 61	−0 02
		0·588 ±0·031	

* Measured with 520 diameters.

This corresponds to a diameter of

2,523 miles,

which is a smaller diameter than has usually been assigned to *Titan*, and would indicate a density about 5·2 times as great as that of *Saturn*.

Conjunctions of Satellites with Ball.

The following careful estimates were made with the aid of a micrometer wire placed perpendicular to the equator of *Saturn*.

Inferior conjunction of *Rhea* and centre of ball, 1894 May $7^d\ 10^h\ 18{\cdot}6^m$ Standard Pacific Time. *Rhea* about 9″ from North limb. Observation good.

Superior conjunction of *Tethys* and centre of ball, 1894 May $7^d\ 11^h\ 2{\cdot}1^m$ Standard Pacific Time. *Tethys* about 3″ from South limb. Observation good.

Inferior conjunction of *Tethys* and centre of ball, 1894 July $15^d\ 8^h\ 40{\cdot}1^m$ Standard Pacific Time. *Tethys* about 2″ from North limb. Observation good.

Mount Hamilton, California:
1895 *January* 27.

Note.—1895 *April* 1.

I am continuing the work of measuring the ball and ring system of *Saturn* through the approaching opposition, and have already secured several sets of measures. They confirm the previous work.

Following are the observations so far obtained:

Centre Cassini Division to Nearest Limb of Planet.

		Preceding			Following		
		Obsd.	M.Δ.	δ.	Obsd.	M.Δ.	δ
Feb.	4	8″·13	8″·16	+0″·10	8″·18	8″·21	+0″·06
	5	8·19	8·20	+0·06	8·12	8·13	+0·14
	18	8·52	8·35	−0·09	8·44	8·27	+0·00
Mar.	3	8·67	8·33	−0·07	8·78	8·44	−0·17
			8·259			8·267	

The values for the "preceding" have been corrected for the phase of the ball.

Adding these to the equatorial diameter of the ball previously obtained gives for the diameter of the Cassini division

34″·270

combining this with the direct measures of this quantity, that follows, we have

$$34''.425$$

for the diameter of the Cassini division—in good accord with last year's result.

Outer Diameter of Rings.

	Obsd.	M.Δ.	δ.
1895 Mar. 4	41".97	40".28	+0".01
10	42.12	40.06	+0.21
24	43.25	40.48	−0.21
		40.273	

Diameter Centre Cassini Division.

	Obsd.	M.Δ.	δ.
1895 Mar. 4	36".03	34".58	0".00
10	36.24	34.47	+0.11
24	37.08	34.70	−0.12
		34.583	

Inner Diameter Inner Bright Ring.

	Obsd.	M.Δ.	δ.
1895 Mar. 4	26".85	25".77	−0".13
10	26.99	25.67	−0.03
24	27.22	25.47	+0.17
		25.637	

Inner Diameter of the Crape Ring.

	Obsd.	M.Δ.	δ.
1895 Mar. 4	21".36	20".50	−0".06
10	21.57	20.51	−0.07
24	21.69	20.30	+0.14
		20.437	

It will be seen that this value is about $\frac{1}{2}$ a second smaller than that previously derived from the measures of the width of the crape ring at the ansæ and the measured diameter of the inner bright ring.

The above values are direct measures of the inner diameter of the crape ring, and are to be preferred to the value of 1894, though it differs considerably from that result. It is not always an easy object to measure, but I think a direct measure of it is best. Determining its diameter in the roundabout way employed in 1894 is subject to an accumulation of errors that the direct measures are free from.

Equatorial Diameter of Ball.

	Obsd.	M.A.	δ.
1895 Mar. 4	18″·43	17″·59	+0″·12
10	18·86	17·94	−0·13
		17·815	

This is corrected for phase.

Polar Diameter of Ball.

	Obsd.	M.A.	δ.
1895 Mar. 4	17″·12	16″·43	−0″·13
10	17·01	16·18	+0·12
		16·395	

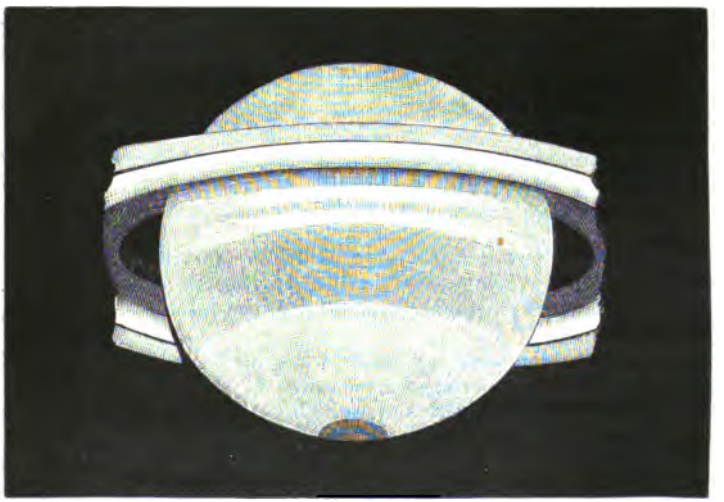
This is not corrected for the elevation of the Earth above the pole of *Saturn*.

It will be seen that these new measures of the position of the ball with reference to the Cassini division, which were made specially to settle the question of any eccentricity of this division, as such seemed to be indicated in the measures of last year, show that the difference in the previous measures of these quantities was simply due to peculiarities in the measures themselves; for the present measures of the distance preceding and following are identical. All the measures therefore go to show that the ball is symmetrically placed in the rings.

Appearance of the Planet in 1895.

The increased opening out of the rings makes the planet a superb object now with the great telescope.

The finest view I have ever had of *Saturn* was on the morning of April 1.



Saturn, 1895 March 31.
(36-inch telescope of the Lick Observatory.)

A stiff south wind was blowing directly on the telescope and making measures impossible, but the definition was superb. During moments of steadiness the view was a sublime one, and impressed me more with the wonderful power of our great telescope than anything else, perhaps, that I have seen through it.

No abnormal features, however, were visible, either upon the rings or on the ball.

The narrow dark belt near the equator, shown in my drawing for 1894, was very distinct, but the space between it and the north dusky region seemed narrower.

This region north of it is really now a very broad warmish dusky belt distinctly terminated at its north edge, which lies about halfway from the trace of the crape ring to the north pole. From the north edge of this belt the surface of the ball was of an exceedingly delicate light yellow, apple-green colour. But at the pole there was a small, very heavily marked dark cap, which was nearly as dark as the crape ring against the sky. This small dark cap was strikingly and sharply defined in outline. I had seen this previously this year, and also last year, but not near so distinctly.

The Encke "division" was seen faintly at both ansæ, but more distinctly following. It was nearly as broad as the Cassini division.

The shadow of the ring on the ball was not visible, but the shadow of the ball on the ring was noticeable preceding the ball. It was narrow, slightly concave, and concentric with the ball. At the following side there was a darkening of the ring and the ball suggestive of the faintest trace of the shadow on that side.

The trace of the crape ring was pale and the ball was easily seen through it up to the bright ring. On the sky it was clearly defined, very distinct, and of a steely blue colour.

1895 *April* 1.

Filar Micrometer Measures of the Diameters of the Four Bright Satellites of Jupiter, made with the 36-inch Equatorial of the Lick Observatory. By E. E. Barnard, A.M., Dr. Science.

The great power and large scale of the 36-inch make it very suitable for measuring very small quantities, such, for instance, as the diameters of the larger asteroids, the satellites of *Jupiter*, and so on.

In connection with my other work on the planet *Jupiter*, I began a series of micrometer measures of the diameters of the four bright satellites with the 36-inch.

These have been continued until the bad weather put a stop to the work. It is scarcely probable that any more satisfactory measures of these satellites will be obtained this winter; I have, therefore, collected and reduced the observations as final.

A power of 1,000 has been uniformly used, and unless the night would permit the use of this magnifying power, and give distinctly defined discs, no measures were attempted.

The measures in each case were made by the method of double distances, three to four settings, before and after reversal of the wires, being made.

The endeavour in these observations has been to exactly bisect the limbs of the satellites with the centres of the wires. This, I think, can be done with an extremely small percentage of error. I should think this method more accurate than that of bringing the insides or the outsides of the wires tangent to the limbs, and then correcting for the thickness of the wires. If the images were absolutely steady and permitted one to deliberately bring the edges of the wires in exact tangency, then that method would be preferred. This condition of things, however, essentially never occurs. The thickness of the micrometer wires in the 36-inch micrometer is about 0″·1.

Following are the details of the measures.

The full aperture of the 36-inch, as always, has been used.

Satellite I.

1894.	Apparent Diam.	At Δ 5.20.	Deviation from Mean.
	″	″	″
Oct. 21	1·08	0·97	+0·08
28	1·02	1·12	−0·07
29	1·13	0·99	+0·08
Nov. 4	1·19	1·07	−0·02
5	1·33	1·14	−0·09
12	1·27	1·07	−0·02
18	1·24	1·03	+0·02
19	1·19	0·99	+0·06
Mean		1·048	

The measured diameters of this satellite are all *equatorial*, except on the following dates, November 4, 5, 18, when the *polar* diameter was measured.

Satellite II.

1894	Apparent Diam.	At Δ 5.20.	Deviation from Mean.
	″	″	″
Oct. 21	0·82	0·73	+0·14
28	0·93	0·81	+0·06
29	0·96	0·84	+0·03
Nov. 4	1·05	0·90	−0·03
5	1·21	1·04	−0·17
12	1·10	0·93	−0·06
18	1·03	0·85	+0·02
19	1·08	0·89	−0·02
Mean		0·874	

All the measures of this satellite are *polar*.

Satellite III.

1894.	Apparent Diam.	At Δ 5.20.	Deviation from Mean.
Oct. 21	1.85	1.66	−0.14
28	1.60	1.40	+0.12
29	1.66	1.45	+0.07
Nov. 4	1.77 (Equ.)	1.50	+0.02
4	1.73 (Pol.)	1.46	+0.06
5	2.03	1.74	−0.22
11	1.86	1.57	−0.05
12	1.77	1.49	+0.03
18	1.79	1.49	+0.03
19	1.86	1.54	−0.02
Dec. 23	1.79	1.43	+0.09
Mean		1.521	

Two measures of this satellite were made on November 4—equatorial and polar. The slight difference doubtless means nothing. All the other measures are *polar*.

Satellite IV.

1894.	Apparent Diam.	At Δ 5.20.	Deviation from Mean.
Oct. 21	1.58	1.41	+0.02
28	1.58	1.38	+0.05
29	1.58	1.38	+0.05
Nov. 4	1.62	1.39	+0.04
5	1.85	1.58	−0.15
11	1.73	1.46	−0.0
12	1.69	1.42	+0.01
18	1.66	1.38	+0.05
19	1.77	1.47	−0.04
Mean		1.430	

All the measures are *polar*.

Results.

We have therefore for the dimensions of these four satellites from the measures with the 36-inch, at distance 5.20—

Satellite	I.	1.048 ± 0.016	(8 nights)
„	II.	0.874 ± 0.022	(8 nights)
„	III.	1.521 ± 0.023	(10 nights)
„	IV.	1.430 ± 0.015	(9 nights)

These correspond to the following values :—

Diameter	I.	2452	± 37 miles
,,	II.	2045	± 51 ,,
,,	III.	3558	± 54 ,,
,,	IV.	3345	± 35 ,,

Early Estimations and Measures of the Diameters of the Satellites.

Numerous early attempts were made to determine the dimensions of these four satellites before telescopes were powerful enough to make proper direct measures of their diameters. A collection of these early efforts is found in the *Vade Mecum* of Houzeau. I shall call on that valuable book for most of the information that follows.

The methods generally employed in these determinations depended upon the known motions of the satellites in connection with the phenomena of eclipse transit occultation, &c.

I shall indicate the method employed by the following initials :—

Entrance into eclipse (E) (this method ought to give too small a value).

Entrance in transit (T).

Entrance in occultation (O).

Measures of the satellite's shadow (S).

This last method I suppose was resorted to because the shadows would be better defined than the satellites' discs.

1693—*Cassini* (E).

I.	II.	III.	IV.
1″·92	1′·97	2′·06	1″·96

This result makes the satellites all essentially of the same dimension, yet his telescope must have shown him that there was really a considerable difference in size.

1734—*Maraldi* (T).

I.	II.	III.	IV.
2″·0	2″·0	2″·2	2″·0

1738—*Whiston* (E).

I.	II.	III.	IV.
1″·98	1″·47	1″·95	1″·64

1771—*Baily* (E).

I.	II.	III.	IV.
1″·9	1′·54	1″·85	...

1788—*Lalande* (E).

I.	II.	III.	IV.
..	...	...	1″·40

1797—*William Herschel* (T and S).

I.	II.	III.	IV.
...	0″·9 (T)	1″·6 (S)	...

1798—*Lalande* (O and T).

I.	II.	III.	IV.
...	...	...	1″·4

1798—*Schroeter* (T).

I.	II.	III.	IV.
1″·16	0″·95	1″·75	1″·18

By combining his measures with those of Harding

I.	II.	III.	IV.
1″·063	0″·870	1″·543	1″·074

by direct measures he got

I.	II.	III.	IV.
1″·15	0″·80	1″·87	1″·17

by measures of the shadows of the satellites on the planet (S)

I.	II.	III.	IV.
...	0″·83	1″·488	1″·273

I have taken the means of these various attempts of this astronomer. They are—

I.	II.	III.	IV.
1″·124	0″·862	1″·663	1″·174

These results of Schroeter are by far the most successful of the early attempts. They are accordant throughout, and differ in minute quantities only from the best determinations made with the most powerful telescopes of to-day. It is certainly a remarkable and highly creditable work for the industrious and accurate astronomer of Lilienthal.

Later Measures of the Diameters.

From this time on the measures were made with telescopes sufficiently powerful to give reliable results, and I shall collect them in tabular form, and have added my own to them.

Filar Micrometer and other Measures of the Diameters of Jupiter's Satellites.
By Different Observers.

Date.	Observer.	I.	II.	III.	IV.
		"	"	"	"
1829	F. Struve	1·015	0·911	1·488	1·273
1856	Secchi	0·985	1·054	1·609	1·496
1863	Mädler	1·200	1·132	1·519	1·300
1871	Engelmann	1·081	0·910	1·537	1 282
1880	Hough	1·114	0·980	1·778	1·457
1891	Burnham	1·112	1·002	1·783	1·609
1894	Barnard	1·048	0·874	1·521	1·430
		Photometric.			
1879	Pickering	0·924	0·866	1·096	0·651
		Interference.			
1891	Michelson	1·02	0·94	1·37	1·31

Engelmann's results are a combination of micrometer measures and observations of the duration of passing the limb of *Jupiter* at transit.

Mr. Burnham's measures were made (with the 36-inch) on one night only, for Professor Michelson, in 1891.

The measures of Michelson were made in 1891, by his method of interference, with the 12-inch equatorial of the Lick Observatory.

Taking the means of these nine sets of measures by nine different observers, omitting Pickering's result for Satellite IV., we have for the diameters of

I.	II.	III.	IV.
1″·055	0″·963	1″·522	1″·395

with which my observations are in good accordance, and from which they differ by

I.	II.	III.	IV.
+0″·007	+0″·089	+0″·001	−0″·035

These measures, made by the same observer with the same instrument and magnifying power, ought to lead to entire confidence in the results of my measures of the diameters of the minor planets, *Ceres*, *Pallas*, and *Vesta* (see *M.N.*, Vol. LIV. No. 9).

The White Equatorial Belt on the First Satellite.

The existence of the white equatorial belt and dark poles of Satellite I. has been amply verified at every favourable opportunity. They are beyond question permanent features of the

satellite, and will always be visible when a favourable transit occurs. At present the transits of I. are projected on the dark reddish south equatorial belt. This condition brings the white belt on the satellite into striking prominence, at the same time that it makes it rather hard to see the dark polar caps. But when the air is steady, with the 36-inch the entire satellite can be seen projected on the dark background. The phenomenon is then very beautiful. The white belt appears like a thin strip 0″·1 or 0″·2 broad, and the polar regions are very dark—almost black. Without close attention the satellite then simply looks like a thin white strip 1″ long by 0″·1 or 0″·2 broad. But careful inspection, with sufficient power, will show the entire satellite—white belt, dark poles and all. The belt is then seen to cut distinctly across the middle of the satellite.

In all the late observations of this satellite the belt seems to be exactly parallel to the belts of *Jupiter*, though at some of the former observations it has appeared inclined a couple of degrees from the Jovian equator.

I have previously called attention to the phenomena of the transits of this moon. When it first enters in transit, it is seen as a small round white spot, sharply contrasted with the dusky edge of *Jupiter*. As it enters further and the contrast is less, it becomes slightly elliptical in the direction of *Jupiter's* equator. As it progresses further, this ellipticity becomes rapidly greater. Presently a moment comes when the dark poles equal the brightness of the background, and they disappear ; the white belt is then alone visible, and the satellite appears as a thin white strip. If the transit should carry it across a bright part of *Jupiter's* surface, the phenomenon of duplicity appears. The white belt is lost in the brightness of the background, and the dark poles appear as two dark spots—entirely separate—making the satellite appear double in a line perpendicular to the equator of *Jupiter*. If, however, in transit, it should be projected on a dark part of the planet, the dark poles in general will be lost in the background, and the satellite will appear very much elongated parallel to *Jupiter's* equator, the white belt alone being seen.

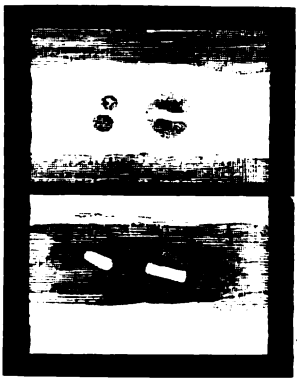
I have looked carefully for any elongation of this satellite when on the sky. Several times I have thought it elongated towards *Jupiter*, but a careful inspection has never convinced me that the elongation was real. With not the best seeing, this appearance of elongation was more decided. Where a casual inspection would seem to show elongation—or polar flattening—a closer inspection would dispel the appearance.

In speaking of his observations of the form of the disc of this satellite with the 36-inch, in a paper dated 1894 June 9 in *Astronomical Journal*, No. 321, vol. xiv., Professor Schaeberle says that to him the disc of I. "appears round only when it is very near to or projected on the disc of *Jupiter*, and elongated in the direction of the planet's equator in all other positions."

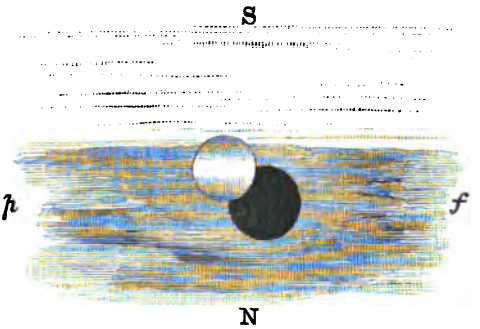
If this were due to a true polar flattening it would suggest a

very rapid rotation of this satellite and not one coincident with its period of revolution. For thus to be seen elongated in essentially all parts of its orbit it must be more or less lens-shaped and not egg-shaped, with the smaller end towards *Jupiter*, or it could not be seen elongated in all parts of its orbit.

Double transit of Satellite I., 1890 September 8.



Satellite I., 1890 September 8 and 1891 August 3, and explanation of the phenomena.



Transit of Satellite I. and its shadow, 1893 November 19; showing the phenomena of bright equatorial belt and dark poles.

Professor Schaeberle has also seen it elongated in transit, for we both watched it one night this winter with the 36-inch, when it appeared as a thin white strip about one second long and about two-tenths second broad projected on the south reddish equatorial belt and parallel with *Jupiter's* equator. At that time, during moments of best seeing, the entire satellite was visible, the poles were very dark—almost black.

I think there is no sort of question but this appearance of elongation on the sky is simply a natural result of the bright equatorial belt and dark polar caps. The satellite actually does become conspicuously elongated when in transit, but no one then watching it would attribute the appearance to a real polar flattening. Now, on the sky this must have a more or less similar effect, through the darkness of the poles and the brightness of its equator. A lack of contrast with the sky in one direction and a good deal of contrast in another, aided by irradiation, and the satellite might well appear elongated towards the planet. This appearance of elongation would doubtless be augmented by indifferent seeing.

I think, therefore, that the dark poles and bright equatorial belt of the first satellite of *Jupiter* thoroughly account for all the phenomena previously reported of the distortion or ellipticity of its disc. This explanation is commended for its simplicity, as it requires no violation of the laws of Nature to satisfy the observation.

It is well here to again make a statement in reference to the discovery of the caps and belt of this satellite. These were discovered by the writer with the 12-inch equatorial of the Lick Observatory, 1890 September 8.

For the facts in connection with this discovery see *A.N.* 2995, p. 318; *A.N.* 3051; *A.N.* 3206, p. 229; *M.N.* vol. li. p. 557, where a drawing is given showing all the phenomena; *M.N.* vol. lii. pp. 14–15; *M.N.* vol. liv. p. 134, where another drawing is given showing the satellite in transit partly occulting its own shadow.

I do not wish it understood that the belt is sharply outlined. It rapidly fades out as it recedes from the equator, but does not terminate abruptly. Or, in other words, the dark polar caps are darkest *at the poles* and become rapidly less intense towards the equator.

I have previously called attention to the fact that this satellite must rotate on an axis almost perpendicular to the plane of its orbit.

I think that the phenomenon of the dark poles of this satellite would rather suggest that its physical condition is not very different from that of *Jupiter*, for the polar regions of *Jupiter* are dark, and so are those of *Saturn*. The density of the satellite is about the same as that of *Jupiter*—another strong proof of actual physical resemblance.

Mount Hamilton, California:
1894 *December* 27.

Observations of the Phenomena of Jupiter's Satellites, and of the Transits of the Red Spot, Dark and Bright Spots, &c., at Bermerside Observatory, Halifax, during the Winter of 1894–1895. By Joseph Gledhill.

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	*N. Almanac* Time.
1894.				h m s	h m s
Nov. 11	(*a*) I.	Ec. D.	Fading	10 4 0	10 8 10
			Half gone (?)	10 5 0	
			Just gone	10 8 40	
14	(*b*) III.	Sh. I.	Internal contact	11 19 30	11 17 0
15	(*c*) II.	Ec. D.	Fading	9 34 7	9 35 21
			Bisection	9 35 34	
			Just gone	9 37 33	
17	(*d*) II.	Tr. E.	Internal contact	7 55 0	7 59 0
			Bisection	7 57 0	
			External contact	8 0 0	
Dec. 1	(*e*) II.	Tr. I.	External contact	9 56 30	9 57 0
			Bisection	9 58 10	
			Internal contact	10 0 0	
	II.	Sh. E.	Internal contact	11 28 0	11 29 0
			Bisection	11 29 30	
19	(*f*) II.	Tr. E.	Internal contact	6 6 0	6 10 0
			External contact	6 11 0	
	I.	Sh. I.	Internal contact	11 28 0	11 25 0
	I.	Tr. I.	External contact	11 30 0	11 30 0
			Internal contact	11 33 0	
20	(*g*) III.	Sh. I.	Internal contact	7 12 0	7 11 0
	(*h*) III.	Tr. I.	External contact	7 22 0	7 26 0
			Bisection	7 26 0	
			Internal contact	7 30 0	
	III.	Tr. E.	Bisection	10 10 0	10 14 0
	I.	Oc. R.	Bisection	10 51 0	10 53 0
			External contact	10 53 0	
	(*i*) I.	Ec. D.	Fading	8 33 30	8 36 2
			Bisection	8 35 0	
			Just gone	8 36 32	
27	(*j*) I.	Oc. D.	External contact	10 20 0	10 21 0
			Bisection	10 22 0	
			Just gone	10 23 20	

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation. h m s	*N. Almanac* Time. h m s
1894. Dec. 27	III.	Tr. I.	External contact	10 37 30	10 41 0
			Bisection	10 42 0	
			Internal contact	10 45 0	
	III.	Sh. I.	Internal contact	11 10 0	11 11 0
	I.	Ec. R.	First seen	12 42 42	12 42 43
			Bisection (?)	12 43 50	
			Full (?)	12 45 20	
29	I.	Ec. R.	First seen	7 11 14	7 11 24
			Bisection	7 12 0	
			Full	7 14 0	
1895. Jan. 2	(*k*) II.	Tr. I.	External contact	8 3 0	8 4 0
			Bisection	8 5 0	
			Internal contact	8 7 0	
	(*l*) II.	Sh. I.	Internal contact	8 38 0	8 37 0
4	(*m*) II.	Ec. R.	First seen	6 12 44	6 13 18
			Bisection	6 14 0	
			Full	6 16 0	
	I.	Tr. I.	External contact	9 20 0	9 23 0
			Bisection	9 22 0	
			Internal contact	9 23 30	
	(*n*) I.	Sh. I.	Internal contact	9 41 30	9 43 0
	I.	Tr. E.	Internal contact	11 42 0	11 39 0
			External contact	11 45 0	
5	(*o*) I.	Oc. D.	Last seen	6 32 0	6 31 0
	(*p*) I.	Ec. R.	First seen	9 5 15	9 6 22
21	(*q*) I.	Ec. R.	First seen	7 25 12	7 25 36
			Bisection	7 27 0	
			Full	7 29 0	
	III.	Oc. D.	External contact	10 0 0	10 5 0
			Bisection	10 3 30	
			Just gone	10 7 45	
25	(*r*) III.	Sh. E.	Internal contact	6 0 0	6 5 0
			Bisection	6 2 0	
	II.	Oc. D.	External contact	9 48 30	9 49 0
			Bisection	9 50 30	
			Just gone	9 53 0	
28	(*s*) I.	Oc. D.	External contact	6 15 30	6 15 0
			Just gone	6 18 0	

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	*N. Almanac* Time.
1895.				h m s	h m s
Jan. 28	I.	Ec. R.	First seen	9 20 45	9 21 0
			Bisection	9 23 0	
			Full	9 25 0	
Feb. 4	I.	Oc. D.	External contact	8 1 0	8 3 0
			Bisection	8 2 30	
			Just gone	8 4 30	
8	(*t*) III.	Tr. I.	External contact	7 1 0	7 0 0
			Bisection	7 3 0	
			Internal contact	7 6 0	
	III.	Tr. E.	External contact	9 51 0	9 51 0
	III.	Sh. I	Internal contact	11 10 0	11 8 0
11	(*u*) IV.	Sh. E.	Internal contact	5 58 0	6 8 0
	(*v*) I.	Oc. D.	External contact	9 50 30	9 52 0
			Bisection	9 52 0	
			Just gone	9 55 20	
12	(*w*) I.	Tr. I.	External contact	7 9 30	7 8 0
			Bisection	7 12 0	
			Internal contact	7 13 30	
	I.	Sh. I.	Internal contact	8 15 0	8 14 0
	II.	Ec. R.	First seen	8 26 28	8 27 44
			Bisection	8 28 0	
			Full	8 31 0	
	I.	Tr. E.	Internal contact	9 22 0	9 25 0
			Bisection	9 24 0	
			External contact	9 26 30	
	(*x*) I.	Sh. E.	External contact	10 27 0	10 31 0
			Bisection	10 29 0	
13	(*y*) I.	Ec. R.	First seen	7 40 54	7 40 56
			Bisection	7 42 30	
			Full	7 46 0	
20	(*z*) I.	Oc. D.	External contact	6 9 10	6 11 0
			Bisection	6 11 0	
			Just gone	6 12 20	
	(1) I.	Ec. R.	First seen	9 36 20	9 36 36
			Bisection	9 38 0	
			Full	9 42 0	
21	II.	Sh. E.	Internal contact	5 35 0	5 40 0
			Bisection	5 37 0	

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	*N. Almanac* Time.
1895.				h m s	h m s
Feb. 21	I.	Tr. E.	Internal contact	5 39 0	5 43 0
			Bisection	5 41 30	
			External contact	5 42 40	
	(2) I.	Sh. E.	Internal contact	6 52 0	6 55 0
26	(3) II.	Oc. D.	External contact	8 34 40	8 36 0
			Bisection	8 37 0	
			Just gone	8 38 50	
	III.	Ec. D.	Fading	8 57 0	9 4 7
			Bisection	8 59 40	
			Just gone	9 5 21	
	I.	Tr. I.	External contact	10 51 7	10 50 0
			Bisection	10 52 40	
			Internal contact	10 54 20	
	(4) III.	Ec. R.	First seen	11 54 23	11 56 34
			Bisection	11 57 0	
			Full	11 59 0	
Mar. 1	(5) I.	Ec. R.	First seen	6 1 7	6 1 18
			Bisection	6 3 0	
			Full	6 5 30	
5	III.	Oc. D.	External contact	7 49 20	7 53 0
			Bisection	7 53 0	
			Just gone	7 55 50	
7	I.	Tr. E.	Internal contact	9 24 20	9 27 0
			Bisection	9 26 0	
			External contact	9 27 50	
16	(6) II.	Ec. R.	First seen	8 6 9	8 7 6
			Bisection	8 8 0	
			Full	8 10 30	
	(7) III.	Sh. E.	Internal contact	10 9 0	10 12 0
21	(8) II.	Tr. I.	External contact	10 54 0	10 59 0
			Bisection	10 56 0	
			Internal contact	10 58 0	
	(9) I.	Tr. I.	External contact	11 2 0	10 59 0
			Bisection	11 2 30	
			Internal contact	11 5 0	
April 7	I.	Ec. R.	First seen	10 8 38	10 8 50
			Bisection	10 10 0	
			Full	10 12 0	

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	*N. Almanac* Time.
1895.				h m s	h m s
April 10	(10) IV.	Oc. D.	External contact	7 52 0	7 55 0
			Bisection	7 56 to 8^h	
			Just gone	8 5 0	
	III.	Ec. D.	Fading	9 3 0	9 6 51
			Bisection	9 6 0	
			Just gone	9 8 8	
	(11) IV.	Oc. R.	Bisection	9 45 0	9 48 0
			External contact	9 48 0	
14	(12) I.	Oc. D.	External contact	8 36 30	8 37 0
			Bisection	8 38 0	
			Just gone	8 39 50	
15	(13) I.	Tr. E.	External contact	8 5^m to 6^m	8 6 0
	II.	Tr. I.	External contact	8 21 0	8 25 0
			Internal contact	8 24 0	
May 8	I.	Tr. E.	Internal contact	8 28 30	8 34 0
			External contact	8 33 0	

Notes.

(*a*) Violent motion. (*b*) Much boiling; shadow not seen till nearly quite on disc. (*c*) Poor definition; high wind; some cloud. (*d*) Planet low. Bad definition. (*e*) Bad definition. (*f*) Planet low. Poor definition. (*g*) Planet low; much motion. (*h*) A difficult observation, the satellite being not far from the South pole of *Jupiter*. The satellite became invisible before 7^h 40^m. (*i*) Satellite entered shadow very close to planet. (*j*) Fair definition to-night. (*k*) Often clouded; much motion. (*l*) Much cloud passing. Satellite invisible at 8^h 20^m. (*m*) Violent motion. (*n*) Much motion. (*o*) Much cloud. (*p*) Definition bad. (*q*) Wind; showers of snow. (*r*) Bad definition. (*s*) Much cloud; hazy. (*t*) Definition not good; misty. (*u*) Good definition. A difficult observation owing to shadow being near South pole of *Jupiter*. (*v*) Definition bad. (*w*) Good definition. Satellite I., in transit, became invisible at about 8^h; not seen again till 9^h 15^m. (*x*) Much motion. (*y*) Very misty. (*z*) Good definition. Very misty. (1) Cloudy. (2) Definition not good. (3) Poor definition. (4) Very bad definition. (5) In early twilight. (6) Bad definition. (7) Much motion. (8) Planet low in W. Poor definition. (9) Bad sky. (10) Much boiling. (11) Bad definition. (12) Bad definition. (13) Violent motion.

Some Transits of Dark Spots on the Dark Belt below (N) Jupiter's Equator.

1. A dark spot which passed about 3½^h before the zero meridian.

Observations.—1894 Nov. 15: 3^h 21^m before the zero meridian. Nov. 17: 3^h 22^m. Dec. 18: 3^h 26^m. 1895 Jan. 2: 3^h 29^m; much motion. Jan. 26: 3^h 30^m; good. Jan. 21: 3^h 34^m; very

bad definition. Feb. 7 : $3^h\ 32^m$; poor definition. Feb. 12 : $3^h\ 35^m$; good definition.

2. A dark spot which passed about $2^h\ 36^m$ before the zero meridian.

Observations.—1895 Feb. 12 : $2^h\ 35^m$; good. Feb. 26 : $2^h\ 38^m$; poor.

3. A dark spot which passed about $1^h\ 8^m$ after the zero meridian.

Observations.—1895 Feb. 8 : $1^h\ 14^m$; fair. Feb. 11 : $1^h\ 15^m$; good. Feb. 13 : $1^h\ 10^m$; fair. Feb. 20 : $1^h\ 9^m$; good. March 11 : $1^h\ 7^m$; bad sky. March 16 : $1^h\ 6^m$; bad sky.

4. A dark spot which passed about $1^h\ 46^m$ after the zero meridian.

Observations.—1894 Dec. 22 : $1^h\ 52^m$; fair definition. Dec. 27 : $1^h\ 45^m$; fair. 1895 Jan. 8 : $1^h\ 47^m$; much motion.

5. A dark spot which passed about $2^h\ 36^m$ after the zero meridian.

Observations.—1895 : Feb. 11 : $2^h\ 35^m$ good. Feb. 13 : $2^h\ 33^m$; fair. Feb. 16 : $2^h\ 34^m$; poor. Feb. 21 : $2^h\ 38^m$ fair.

6. A dark spot which passed about $3^h\ 47^m$ after the zero meridian.

Observations.—1895 Jan. 23 : $3^h\ 51^m$; fair. Jan. 25 : $3^h\ 52^m$; bad. Feb. 4 : $3^h\ 49^m$; fair. Feb. 16 : $3^h\ 41^m$; bad. Feb. 21 : $3^h\ 47^m$; fair. March 7 : $3^h\ 41^m$; fair.

Some Transits of Bright Spots on the same Dark Belt.

1. 1895 Feb. 12 : $1^h\ 39^m$ before the zero meridian.

2. 1895 Jan. 26 : $1^h\ 27^m$ before the zero meridian.

3. 1895 Jan. 24 : $2^h\ 12^m$ before the zero meridian. Jan. 26 : $2^h\ 9^m$. Feb. 12 : $2^h\ 11^m$.

4. 1895 Feb. 7 : $4^h\ 15^m$ before the zero meridian.

5. 1894 Dec. 22 : $1^h\ 7^m$ after it. Dec. 27 : $1^h\ 0^m$.

6. 1895 Jan. 23 : $3^h\ 36^m$ after it. Jan. 30 : $3^h\ 32^m$. Feb. 4 : $3^h\ 32^m$. Feb. 11 : $3^h\ 28^m$. Feb. 16 : $3^h\ 29^m$. Feb. 21 : $3^h\ 32^m$.

Dark Spots on the Dark Belt above (S) the Equator.

1895 Feb. 21 : $2^h\ 39^m$ after the zero meridian. And April 10 : $4^h\ 48^m$ before it.

Transits of the Highest Point of the Slanting Belt close behind the following end of the Red Spot.

1895 Feb. 13 : $0^h\ 36^m$ after the zero meridian. Feb. 20 : $0^h\ 34^m$. March 11 : $0^h\ 40^m$. April 9 : $0^h\ 37^m$.

Transits of Mouths of Bright Sinuous Canals in South Equatorial Band (dark).

1895 Feb. 8: $3^h\ 7^m$ after the zero meridian. Feb. 21: $2^h\ 25^m$ after the zero meridian.

The zero meridian used is Marth's II.

The bright spots were on the lower (N) edge of the dark belt.

Transits of the Red Spot.

	Transit of Red Spot.	Transit of Zero Meridian.	Interval.	
1894.	h m	h m	m	
Dec. 12	9 52	9 45	7	Hazy sky.
19	10 37	10 29	8	Spot very faint.
1895.				
Jan. 25	6 2	5 59	3	" " "
Feb. 7	11 47	11 41	6	Misty.
8	7 39	7 33	6	Spot faint.
12	10 53	10 50	3	Bad definition.
20	7 32	7 28	4	Good definition.
Mar. 11	8 17	8 13	4	Bad sky.
16	7 28	7 23	5	" "
Apr. 9	7 25	7 19	6	Much motion.

Dark Transit of Satellite III.

1895 Feb. 8: Satellite III. passed on to the disc at about $7^h\ 3^m$. It was invisible at $7^h\ 30^m$. At 8^h and until about half an hour before egress ($9^h\ 51^m$) it was seen as a dark (not black) circular spot.

In all the preceding observations Greenwich Mean Time was used; and the instrument used was the 9½-inch Cooke Equatorial Refractor: powers 240, 330, and 470.

Note on the Red Spot.—Between 1894 November and 1895 March this object was carefully examined whenever visible. It was never seen with ease and distinctness—was always somewhat difficult. No colour was seen in it; in fact, it was simply an elliptical outline. The best views of it were usually obtained before and after it had passed the central meridian.

The transits were made by placing one web of the micrometer on one limb of *Jupiter*, the other web bisecting the disc.

Photograph of the Nebula near 15 Monocerotis.

By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebula near 15 *Monocerotis*, R.A. $6^h\ 35^m$, Decl. 10° 0′ north, was taken with the 20-inch reflector on 1895 February 13, with exposure of the plate during three hours, and the copy now presented is enlarged to the scale of 1 millimètre to 24 seconds of arc.

References to the star and to the region around it will be found in the *New General Catalogue*, No. 2264; *The General Catalogue*, No. 1440; Sir J. Herschel's *Catalogue of Nebulæ and Clusters of Stars*, No. 401; Lord Rosse's *Observations of Nebulæ and Clusters of Stars*, p. 53; and Professor Barnard in *Astronomy and Astro-Physics*, vol. xiii. pp. 178, 182.

Sir J. Herschel and Lord Rosse suspected 15 *Monocerotis* to be a nebulous star, or else involved in nebulosity, but they could not detect any nebulosity in the region surrounding the star. Professor Barnard took three photographs of this region in 1894 January and February, and upon them found "nebulosity covering a diameter of about three degrees," and he states that "at 12 minutes of arc *south preceding* 15 *Monocerotis* the nebulosity becomes a compact mass with numerous wisps and holes in it, and the whole group of three or four bright stars is involved in this denser wispy light, but 15 *Monocerotis* itself does not seem to be specially connected with the nebulosity further than to be apparently in it—that is, there are no indications of condensation about the brightest star of the group."

The photograph now presented, and the lantern slide which is projected on the screen, show a multiple star at position angle 219° and distance 8′ 8″ from 15 *Monocerotis*, and this is about the centre of the large condensation of the nebulosity. At position angle 173° and distance 29′ 52″ from 15 *Monocerotis* is the apex of a conical dark space bounded by a rim of nebulosity, and at the apex also are three stars, one about 14th, another about 15th, and the other about 17th magnitude. The space between these and the multiple star is faintly nebulous, and there is also a faint detached curve of nebulosity at position angle 8° and distance 19′ from 15 *Monocerotis*.

Professor Barnard has sent to the Society a positive copy on glass of his photograph of the region surrounding 15 *Monocerotis*, and a lantern slide has been made from it to the scale of the photograph which I have just exhibited. It is now projected on the screen, and you will at once recognise the vast difference between a photograph taken with a small camera and one taken of the same region with a comparatively large reflector. The reflector photograph shows clearly the fine details of the nebulosity and their relationship with the involved and surrounding stars, and also that the stars are far more numerous on

the reflector than they are on coincident areas on the camera photograph. The photo-discs of the stars on the camera photograph are largely out of proportion with the corresponding discs on the reflector photograph, and these large discs cover often several of the near stars which the larger instrument resolves into their separate components. There are vast areas on the camera photograph which to most of us would be accepted as evidence of nebulosity with dark tortuous rifts in it, but it is not nebulosity at all. It is in fact the effect of the diffused light of numerous and close stars being concentrated upon the photo-film by a small instrument, and the dark rifts are only areas with fewer stars on them; hence they aid in deceiving the eye, by causing the appearance that the crowded star areas are involved in true nebulosity. The lantern slide made from Professor Barnard's plate and now projected on the screen will serve as an illustration of these statements.

Photograph of the Crab Nebula M. 1 Tauri.
By Isaac Roberts, D.Sc., F.R.S.

The photograph of the nebula *M.* 1 *Tauri*, R.A. $5^h\ 28^m$, Decl. 21° 57′ north, was taken with the 20-inch reflector on 1895 January 25, with exposure of the plate during one hour, and the copy now presented is enlarged to the scale of 1 millimètre to 6 seconds of arc.

Two enlarged photographs of this nebula, with an exposure of three hours, were presented to the Society in 1892 May (*Monthly Notices*, vol. lii. p. 502), and this one, with an exposure of sixty minutes, shows less densely the extensions of the nebulosity which are shown on those of 1892; and the mottling, and star-like condensations within the denser parts of the nebula, are better seen on this photograph.

All the stars that are shown on the photograph of 1892 are also visible on this, and there is no obvious change in position angles or in brightness of the stars, or in the nebulosity, during the interval of three years between their respective dates.

Dark curved rifts are on the negative conspicuously visible in the dense parts of the nebula, and some of the nebulosity is visible in wispy curves and in condensations more or less star-like. The whole nebula is unsymmetrical in form, and when studied in connection with the descriptions herein given is suggestive of a state of great disturbances internally. One of the dark rifts referred to forms almost a straight line in *nf* and *sp* direction across the centre of the nebula, and has a star of about 15th magnitude at its centre; another rift forms a triple curve along the north margin of the nebula and extends nearly its whole length from the *south following* end to its *north preceding* end, where it stretches across the nebula to the *south* side.

Notwithstanding the evidence we have of great disturbances

affecting the substance of this nebula, the interval of three years since the first reliable records of its form and internal details were obtained is insufficient to enable me to say that any change has taken place in its structure; but this need cause no surprise, for I have compared a photograph of the great nebula in *Orion* which was taken in 1886 October with another taken in 1894 February, the interval between them being seven years and four months, and although that nebula appears also to be in a state of violent commotion, I have been unable to find that perceptible changes have taken place in the structure of the nebulosity.

Our work, therefore, is to make, preserve, and publish accurate records of the present state of these celestial bodies on a scale sufficiently large to show their structure, and trust that our successors of twenty or thirty years hence will by repetition of our processes obtain data for largely increasing astronomical knowledge.

Note on a Suggested Form of Equatorial Mounting for a (modified) Newtonian Reflector. By Rev. Charles D. P. Davies, M.A.

Attention having been drawn by Dr. Common at the meeting in January to a modified form of Cassegrain reflector, and the general subject of reflectors having been thus brought into prominence, I beg to submit the following ideas, which I have long had in mind, on a modified form of Newtonian equatorial.

First as regards the telescope; second as regards its mounting.

For the form of the telescope I claim no novelty, as I remember seeing it suggested some years ago—I think by Mr. Brashear. It is essentially a modification of the Newtonian. The speculum, both in itself and in its position, is entirely Newtonian. But at the upper end of the tube is an elliptical flat, set at an angle of 45°, having its minor axis equal to the diameter of the speculum; that is to say, it fills up the tube. This flat is the first glass to receive the rays of light, which are admitted by a suitable opening in the side of the tube. The rays reflected at a right angle pass, still parallel to each other, down to the speculum, whence they are returned to a hole in the centre of figure of the flat. Through this hole they pass to the eyepiece.

S speculum, F flat, E eyepiece.

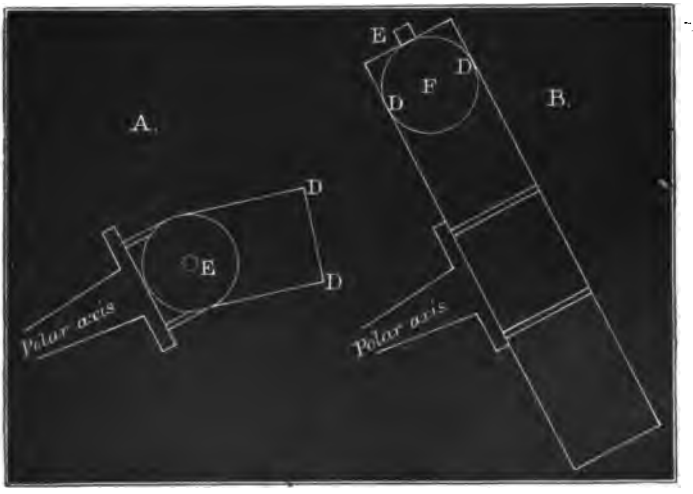
Fig. 1.

Optically the instrument is perfect—at least there is no distortion. There is only the usual number of two mirrors of the usual Newtonian figure.

The observer is well removed from the opening of the tube, so that the interference of heated air from his body is avoided—at least quite as much as it is in the ordinary Newtonian.

But compared with the latter this form has two very distinct advantages. First, there is a complete absence of the troublesome flare and "wings" produced by the steel strips generally employed for the suspension of the ordinary flat; and not only so, but there is also an absence of the defection of light caused by their intervention; and to both of these there is to be added the fact that the hole for the eyepiece, except in small telescopes, would probably not be nearly so large in diameter as the cell of the common flat. Secondly, the occurrence of tarnish. A spot of tarnish of given diameter (say ½ inch) on an ordinary flat (say 2 or 3 inches minor axis) affects an immensely greater proportion of the total light than would be affected by a spot of the same diameter on the larger flat proposed.

I am far from wishing to be blind to any difficulty. The larger flat would of course be more expensive not only owing to its size, but by reason of the necessary drilling of the hole. (Possibly this might be avoided by their being cast ready of the required form.) But this drawback once fairly stated I must confess that at present I can see no other.



(A) In the meridian viewing a circumpolar star at its lower culmination.

(B) Six hours from meridian viewing the rising of an equinoctial star.

Both elevations from the East.

Fig. 2.

As regards fixing the flat much the same lines would naturally be adopted as those in general use for specula. The question of dew might easily be met by any desired prolongation of the circular opening D D made of almost any light material.

I come now to the second but chief point in the present paper. This is the question of the mounting. It appears to me that this form of telescope is eminently suitable for mounting as an equatorial. I would mount it as follows:—I would put the telescope itself in the position generally occupied by the declination axis. That is to say, I would put it across the centre of the upper end of the polar axis, with its axis of collimation at right angles to the polar axis, making it revolve for declination on its axis of collimation. That is to say, the line of collimation of the telescope will be the declination axis.

Among the advantages of this form of mounting it seems to me that we can reckon on the following:

(1) Absence of that most undesirable of all adjuncts, the counterpoise, that terrible mass that doubles the weight to be carried by the two axes, besides taking up much valuable space in the dome.

Appended to this consideration it may also be observed that there is an absence not only of the counterpoise, but of the declination axis itself with still further consequent lightening of the weight to be borne by the polar axis.

(2) Increase of stability of the instrument, inasmuch as not only is the telescope firmly held on either side of its centre of gravity by the brackets attached to the upper end of the polar axis; but carried, as it is, immediately on that axis instead of being held out at arm's length from it, there must be far less liability to flexure, the great enemy of exactitude, and equally less liability to tremor.

(3) With this mounting the telescope is perpetually free for actuation by the clock. No position can be reached in which it must be reversed to the other side of the stand. The telescope may be directed to any star, the clock started, and left to do its work for twenty-four hours if necessary.

(4) Possibility of uniform height of the eyepiece above the observer's standing or sitting level in every position of the telescope. This I would secure by a circular platform or gangway of suitable diameter around the instrument in the plane of the equinoctial. With a little simple adaptation or variation this could be managed even in the proximity of the equator. In our own latitude the platform would consist of steps of moderate gradient, while in the high latitudes it would become little, if anything, more than a gentle slope. An observing chair could be made to suit the steps and gradient of the platform. No screwing up or

down ladders, no hydraulic or other lifting and depressing of floors.

(5) At all times and in all positions of even the largest telescope, every part of it along its whole length from speculum to eyepiece is within reach of the observer or his attendant, without climbing of any sort.

(5a) Attachment of handles for slow motion in R.A. and Dec. would be greatly simplified.

(6) As the rotation of the tube in its cradle would form the setting for declination, it is manifest that any necessity for that process during the progress of a lengthened observation would entirely vanish.

(7) Absolute freedom of view to any part of the celestial vault. The whole heavens would be open to the instrument without any need of reversal from E to W, or *vice versâ*. Here is an advantage over any other non-counterpoised form of mount that I know. Take for instance the "hay-fork" mount. Unless the prongs of the fork are too long for complete stability, there is a certain amount of restriction to the scope of the instrument. And having mentioned the "hay-fork" I may add that when its telescope is at any considerable distance from the meridian there must be a very unfair amount of weight and cross strain on the prong that for the time being is lowest.

(8) Last but not least, a saving in the size of the dome, and therefore in its weight, and in the size and expense of the whole observatory—a saving that might easily more than compensate for the form and larger size of the flat.

Observations of Minor Planets made with the 15-inch Equatorial of the National Mexican Observatory, Tacubaya.

By Felipe Valle.

(*Communicated by the Secretaries.*)

Long. W. 6h 36m 46s·53. Lat. N. 19° 24′ 17″·5.

Date.	Mean Time.	Planet − ✱ Δα.	Planet − ✱ Δδ.	No. of Comps.	Planet App. R.A.	Log (ρ × Δ) of Parallactic Factor.	Planet App. Decl.	Log (ρ × Δ) of Parallactic Factor.	Red. to Day.	No. of Comp. Star.
					(176) *Idunna.*					
1894.	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Oct. 3	11 32 58	+1 41·11	−1 05·85	5, 5	0 20 52·16	7·971+	+10 29 27·9	0·131+	+3·44 +23·90	1
6	10 52 47	−1 17·21	−1 37·58	4, 4	0 19 05·47	8·766n	+ 4 47 39·8	0·209+	+3·46 +24·15	2
8	11 20 03	−0 38·34	−0 26·80	6, 6	0 17 54·04	8·522+	+ 9 19 39·9	0·185+	+3·46 +24·15	3
9	10 06 56	−0 58 34	+4 10·40	6, 6	0 17 21·73	9·129n	+ 9 02 10·4	0·200+	+3·48 +24·32	4
10	8 53 05	+2 01·00	−3 10·41	5, 5	0 16 49·63	9·465n	+ 8 53 32·3	0·251+	+3·47 +24 24	5
11	8 47 29	−1 37·39	−6 22·32	6, 6	0 16 17·13	9·469n	+ 8 39 49·8	0·259+	+3·48 +24·35	6
					(90) *Antiope.*					
Oct. 6	10 53 31	−2 12·31	+2 12·06	5, 5	0 51 52·10	9·122n	+2 22 16·2	0·412+	+3·55 +24·82	7
9	11 17 36	+3 52·01	−1 11·48	5, 5	0 49 33·30	8·607n	+2 09 22·6	0·416+	+3·56 +24·64	8
11	9 47 09	+1 06·36	+0 50·39	7, 7	0 48 05·26	9·363n	+2 01 19·2	0·423+	+3·57 +24·58	9
					(87) *Sylvia.*					
Oct. 26	8 48 02	+0 18·96	+1 32·50	5, 5	2 22 24·30	9·256n	+3 05 25·0	0·418+	+3·75 +25·23	10
30	9 40 22	−0 17 85	−1 55·36	10, 10	2 19 17·10	9·449n	+2 58 55·1	0·405+	+3·79 +25·14	11
31	9 37 02	−1 03·98	−3 18·98	10, 10	2 18 30·97	9·444n	+2 57 31·5	0·383+	+3·79 +25·11	12

Comparison Stars.

No. of Comp. Star.	α 1894·0	δ 1894·0	Authority.	Date 1894.	Difference between observed and calculated positions. Obs. Δα.	Calc. Δδ.	Ephem.
	h m s	° ′ ″			s	″	
2	0 20 19·22	+9 48 53·2	B.D. +9°, 41 (9·0)	...	...	...	...
4	0 18 16·69	+9 02 35·7	B.D. +8°, 41 (8·7)	...	...	...	...
5	0 14 45·16	+8 56 18 5	B.D. +8°, 32 (8·9)	...	...	...	...
6	0 17 51·04	+8 45 47·8	B.D. +8°, 39	...	...	...	...
7	0 54 01·01	+2 19 37·9	Anon. 10·5 Ref. to 500 Yarn.	Oct. 6	−3·59	−14·5	Astr. Jahrbuch
8	0 45 37·51	+2 10 09·12	440 Yarn.	9	−3·23	−14·6	,,
9	0 46 55·33	+2 00 04·2	Anon. 9·7 Ref. to No. 8	11	−3·20	−13·2	,,
10	2 22 01·59	+3 03 27·30	B.D. +2°, 379 −O.A. Merid. Circ.	26	−0·76	− 2·4	,,
11	2 19 31·16	+3 00 25·3	B.D. +2°, 370 −Ref. to Nos. 10, 12	30	−0·71	− 3·8	,,
12	2 13 40·13	+3 02 53·2	B.D. +2°, 358 −O.A. Merid. Circ.	31	−0·75	− 3·8	,,

1	Δα = +1 m 31·64 s	Δδ = −3 ′ 50·02 ″	Ref. to B.D. +10°, 39 (9 3)
3	Δα = +3 28·83	Δδ = −0 47·49	Ref. to B.D. + 9°, 30 (8 8)

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. JUNE 14, 1895. No. 8

Dr. A. A. COMMON, LL.D., F.R.S., President, in the Chair.

Rev. T. Dunne Parker, LL.D., Bennington House, Stevenage, Herts;
John A. Ferguson, Newlands, Oak Hill, Surbiton, S.W.;
George Andrews Hill, United States Naval Observatory, Washington, D.C., U.S.A.; and
Edward William Hobson, Fellow of Christ's College, Cambridge,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Major Kingsley Foster, Shenley, Redhill (proposed by Sir R. S. Ball);
The Rev. Henry A. Hall, M.A., Head Master of the Grammar School, Totnes, South Devon (proposed by E. J. Stone);
Rhishard Llewelyn Jones, M.A. (Cantab.), Professor of Physics, The Presidency College, Madras (proposed by C. Michie Smith); and
Herbert Savery, M.A., Assistant Master at Marlborough College, Wilts (proposed by R. A. Sampson).

Eighty-three presents were announced as having been received since the last meeting, including, amongst others :—

Th. Brédikhine, Mouvement des substances émises par les Comètes 1893 II. et IV. ; H. S. Davis, Parallax of *η Cassiopeiæ*, deduced from the Rutherfurd photographic measures, presented by the authors ; Potsdam Observatory Publications, vol. vii. pt. 2 (Scheiner, Spectra der helleren Sterne), and vol. x. (Spoerer, Beobachtungen von Sonnenflecken), presented by the Observatory ; The Calendarium of Mohammed Al Achsasi Al Mouakket (Arabic MS.), presented by Mr. Knobel.

Reproduction of Astronomical Photographs.

The Council have recently decided to undertake the reproduction (by paper prints and lantern slides) of a selection of the Astronomical photographs now in the possession of the Society, or which may be submitted to the Society for the purpose.

To include any large number of such reproductions in the ordinary publications of the Society, which are distributed gratis, would not be possible unless the subscription were raised. Again, the selection of a small number from the wealth of excellent photographs now being produced would be not only invidious but extremely difficult.

In view of these considerations it seemed the easiest course to try how far the sale of such prints at approximately cost price would satisfy the requirements of astronomers. The Society would thus act as a convenient centre for receiving photographs intended for reproduction and distributing the prints, but would not be interested financially in the undertaking.

In accordance with the decision of Council several photographs have been already reproduced. The list given below shows those of which copies are now on sale ; others will follow. The prints are in two styles—platinotype and aristotype—mounted on sunk, cut-out mounts measuring 12 by 10 inches, and the price has been fixed at 1*s.* 6*d.* each.

In ordering prints it will only be necessary to quote the R.A.S. reference number. Orders to be addressed to W. H. Wesley. Full details as regards subject, instrumental data, exposure, &c., will be found on the back of each print. A set of specimen prints may be seen in the Library.

Suggestions will be gratefully received, either as to subjects of which reproduction is desirable or as regards any of the details.

The following prints are now on sale :—

R.A.S. Reference No.	Subject.	Photograph by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the Pleiades	Isaac Roberts
5	Nebula M. 74 Piscium	Isaac Roberts
6	Great Nebula in Orion	Isaac Roberts
7	Milky Way near Messier II.	E. E. Barnard
8	Milky Way near Cluster in Perseus	E. E. Barnard
9	Comet *c* 1893 IV. (Brooks)	E. E. Barnard
10	Comet *a* 1892 I. (Swift)	E. E. Barnard
11	Nebula about η Argûs	David Gill
12	Portion of Moon (Hyginus-Albategnius)	MM. Lœwy and Puiseux

Arrangements are also being made for the supply of lantern slides prepared from the photographs in the possession of the Society. Further particulars respecting these will be issued as soon as the arrangements are complete.

A Determination of the Mean N.P.D. 1790 *January* 0, *of γ Draconis from Observations made at Oxford by Dr. Hornsby.* By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The Radcliffe Observatory, Oxford, was built about the year 1771, by the Radcliffe Trustees at the request of the University authorities, and furnished with the best instruments available at the time.

The equipment for the meridian observations consisted of two brass quadrants of 8 feet radius, a zenith sector of 12 feet focal length, and a transit instrument with an object glass of 4 inches. The mechanical parts of these instruments, and the divisions, were the work of the celebrated mechanician John Bird, and the optical work was by Dollond. There was no observatory in the world better equipped with meridian instruments than the Oxford Observatory at its foundation.

The quadrant and transit observations made by Dr. Hornsby in the year 1774, and in many subsequent years, were copied by him into books; but the papers generally are in great confusion. Dr. Hornsby reduced some selected observations for special purposes; but the observations have never been regularly reduced, nor, so far as I can find, have they been published in any form which would render them available for the use of astronomers.

The completion of the "Radcliffe Catalogue of 6,424 Stars for 1890" has afforded me the necessary leisure to take into con-

sideration the desirability of reducing some of the old observations made at the observatory.

An examination and partial reduction of the observations made with the quadrant and transit in the year 1774 have satisfied me that the observations are of very considerable accuracy.

I have therefore determined to completely reduce the observations of the year 1774 as a test of the expediency of a more extended reduction of these back observations. There are many considerations which appear to render these reductions desirable. We are relying for our determinations of many of the more important constants of astronomy upon the freedom of the observations made by Bradley at Greenwich, 1750–1762, from serious systematic errors; and our confidence is probably justifiable. But it was clearly shown by Le Verrier in his discussion of the solar observations that, when accurate meridian work was commenced at Paris about 1801, and at Königsberg about 1816, the results obtained were not in satisfactory agreement with the corresponding Greenwich results; and, if the Greenwich results were not then free from serious systematic errors, the question naturally arises, Up to what epoch are we justified in accepting them as free from such errors?

It appeared to me that some light might probably be thrown upon this question by a reduction of the observations made at Oxford about 1774; and, as an additional inducement to undertake the labour of these reductions, I find that a considerable number of observations of the Moon were made at Oxford about this period, which is a critical one in the lunar theory from the magnitude at that time of the doubtful theoretical inequality which Hansen has introduced in the construction of his Lunar Tables.

But as a preliminary step to the complete reduction of the quadrant observations, it has been thought desirable to examine the values of the zenith distances of *γ Draconis* at Oxford for the meridian transits which result from the zenith-sector observations; and the results thus obtained are given in the present paper.

It may be mentioned that the zenith-sector micrometer has two scales—one giving the number of completed revolutions up to eighteen, the other the divisions and decimal parts of a division—and that Bird cut the screw so that one revolution was very nearly equivalent to 27″ of the sector arc. This equivalence was very nearly exact when the instrument was first mounted and adjusted by Bird, and it has been assumed to be exact by Hornsby in his reductions; but I have corrected the results for run whenever readings at consecutive three-minute divisions of the sector arc have been available.

I have also reduced all the observations with the values of the coefficients of aberration, nutation, and precession which are at present usually employed. A few sector observations were made in

1775 with a non-achromatic object glass: I have not at present reduced these observations. In 1777 an achromatic object glass by Dollond was mounted on the zenith sector, and a few observations were made in 1777 and 1778. I have reduced these observations. But during this period the observations were made with a direct eye-piece instead of with a far more convenient diagonal eye-piece first introduced in April, 1778. The desirability of measuring the star's ZD from two adjacent divisions of the sector arc was not apparently so fully recognised as was subsequently the case; the collimation error was unduly large; and there are no sufficient checks upon the constancy of the collimation error, sector east and west, for the observations which have to be combined. The line of collimation was considerably altered by Hornsby in 1778, when he introduced the diagonal eye-piece.

In the reduction of these sector observations it is necessary to assume that the line of collimation remains sensibly unchanged during the whole period for which the sector observations, east and west, are combined, and the only proof of this assumed constancy of the line of collimation is the agreement of the results thus obtained. It would have been more satisfactory if the zenith sector had been reversed oftener than was the case, but a combination of all the observations made, 1788–1791, shows that the changes of the line of collimation of the Oxford zenith sector must have been confined within small limits during this period; and the results thus obtained would, therefore, appear to be entitled to greater weight than those given by the observations 1777–1778, when the constancy of the line of collimation was more doubtful.

The latitude of the zenith sector is very nearly the same as that of the transit circle of the observatory; and if we assume the colatitude to be

$$38^\circ\ 14'\ 24''{\cdot}61,$$

and the proper motion of γ *Draconis* in N.P.D. to be $+0''{\cdot}028$, we deduce from the sector observations the following values for the mean N.P.D. 1790 January 0 :—

	From Observations.	No. of Obs.	Weight.	Mean N.P.D.
	Sector East.			
1	1788 Oct. 7 to Dec. 31	13	10·5	38° 28′ 50″·92
2	1789 Feb. 12 to Feb. 15	2	2	49·48
3	1791 Jan. 4 to Feb. 28	12	11	48·89
4	1791 Sept. 10 to Sept. 25	9	9	50·64
5	1791 Oct. 23 to Dec. 28	7	7	50·50
	Sector West.			
6	1789 Jan. 1 to Feb. 10	14	13·5	44·81
7	1790 Oct. 15 to Dec. 30	15	15	44·91
8	1791 Sept. 26 to Oct. 19	12	12	45·59

These separate results show that no great changes in the line of collimation took place between 1788 October 7 and 1791 December 28; and if we assume the collimation error to be sensibly constant for this period, we find for the mean collimation error, c, and the N.P.D. of γ *Draconis* the following values :—

Mean N.P.D. of γ *Draconis* 1790 Jan. 0 = 38° 28′ 47″·61 $\quad c = +2''{\cdot}52$

and the separate residuals, which include errors of observation and changes of the line of collimation from the mean line are—

	Sector East.		*West.*
	″		″
1	+0·79	6	−0·21
2	−0·65	7	−0·18
3	−1·24	8	+0·50
4	+0·51		
5	+0·37		

The observations made, 1777–1778, lead to a larger result for the N.P.D., viz.

$$\frac{E+W}{2} = 38° \; 28' \; 50''{\cdot}44.$$

If we combined this result with that deduced from the observations, 1788–1791, with the full weight due to the number of observations, we should find

$$\text{N.P.D.} = 38° \; 28' \; 47''{\cdot}95.$$

But, for the reasons given, this is certainly allowing too much weight to the earlier observations. The N.P.D. of γ *Draconis* given by Dr. Auwers in his re-reduction of Bradley's observations brought up to 1790 January 0 is

$$38° \; 28' \; 48''{\cdot}34;$$

and this result appears to me to agree as closely as could have been expected, with the instruments available, with that found from the Oxford observations, 1788–1791 :—

$$38° \; 28' \; 47''{\cdot}61.$$

In the following reductions, when the run over 3′ has not been found from the observations, the adopted quantities have been put in brackets, and only half-weight has been given to these results.

Observations of γ Draconis with the Zenith Sector.

Date.	Division.	Reading of Micrometer For Division.	Reading of Micrometer For Star.	Nominal Seconds of Micrometer in Run over 3′.	Apparent Z.D. (Uncorrected for Refraction.)	Mean Z.D. for 1778 Jan. 0.
			Sector E.			
1777. Nov. 7	12	3 21·9	17 20·5	(180·0)	° ′ ″ 0 13 49·40	° ′ ″ 0 14 5·17
Dec. 16	12	10 4·5	5 17·5	179·7	0 14 2·20	5·91
	15	3 13·8				
27	12	8 9·0	3 15·5	180·8	7·92	7·27
	18	12 25·4				
29	12	13 0·0	8 5·5	179·6	9·79	8·41
	15	6 9·4				
1778. Jan. 21	12	8 0·5	2 22·5	(180·1)	19·92	10·58
22	12	15 10·5	10 6·2	180·3	19·07	9·41
	15	8 19·2				
Feb. 28	12	15 25·7	10 13·3	(182·0)	25·78	7·68
			Sector W.			
1778. Jan. 25	15	12 15·6	11 17·6	(181·8)	0 14 35·25	0 14 24·68
26	12	7 25·5	13 17·3	181·3	32·70	21·82
	15	14 17·8				
Feb. 13	12	7 14·0	13 16·9	181·9	43·18	27·64
	15	14 6·9				
14	12	3 23·2	9 23·2	181·3	40·84	25·08
	15	10 15·5				
17	15	3 18·7	3 1·0	(181·8)	42·48	26·12
23	15	9 1·0	8 12·3	(181·8)	44·46	27·06
25	12	7 3·8	13 9·0	182·6	44·82	27·12
	15	13 24·4				

Between 1778 Jan. 26 and Feb. 9 the sector was reversed from west to east and again brought back to position west; but no observations of γ *Draconis* were made in position east. The line of collimation would almost appear to have been shifted at the time by Dr. Hornsby, although I can find no notice of any such change.

1778 Feb. 28. The runs have been adopted from observations of α *Cygni* after the reversal from position west on Feb. 25.

A diagonal eye-piece was mounted on 1778 April 9; the observations before this period were made with a direct eye-piece.

Date.	Division.	Reading of Micrometer For Division.	Reading of Micrometer For Star.	Nominal Seconds of Micrometer in Run over 3′.	Apparent Z.D. (Uncorrected for Refraction.)	Mean Z.D. for Jan. 0.
			Sector E.			
1788.	′	r d	r d		° ′ ″	° ′ ″
Oct. 7	12	6 22·7	2 5·5	(182·5)	0 14 3·48	0 14 24·43
8	12	6 25·5	2 9·2	181·9	3·00	23·87
	15	0 5·6				
9	12	7 0·0	2 8·9	184·7	2·89	23·67
	15	0 4·3				
Dec. 4	12	5 15·8	0 11·1	(182·7)	17·64	26·52
12	12	11 12·5	6 2·1	(182·7)	23·25	29·36
15	12	11 10 8	6 3·6	(182·7)	20·10	25·20
17	12	17 10·1	12 5·9	182·8	17·07	21·50
	15	10 16·3				
21	12	17 12·5	12 4·5	181·3	21·97	24·68
	15	10 20·2				
*22	12	17 14·8	12 5·6	(181·5)	23·01	25·38
23	12	17 14·3	12 1·6	181·8	26·24	28·26
	15	10 21·5				
26	12	17 12·9	12 2 8	182·1	23·43	24·42
	15	10 19 8				
27	12	17 14·1	12 2·9	182·5	24·20	24·84
	15	10 20·6				
31	12	7·1	12 24 0	180·8	24·46	23·72
	15	11 15·3				
			Sector W.			
1789.						
Jan. 1	12	2 6·7	7 14·3	182·0	0 14 21·03	0 14 20·35
	15	8 26·7				
7	12	2 11·0	7 16·4	180·5	20·01	17·29
	15	9 2·5				
†11	12	2 11·8	7 17·2	173·7	25·49	21·45
	15	8 23·5				
13	12	2 5·4	7 17·3	182·9	24·57	19·87
	15	8 26·3				
16	12	2 4·4	7 14·7	182·4	23·39	17·74
	15	8 24 8				

* On 1788 Dec. 22 an observation was made with reference to division 18 for which the reading for the division was entered as $4^r\ 19^d{\cdot}0$. There is little doubt that the micrometer has been read backwards, and should be $4^r\ 8^d{\cdot}0$. It has been thought better to reject the observation than to make this conjectural alteration.

† 1789 Jan. 11. The observation is correctly reduced from Dr. Hornsby's MS., but the run appears unusually small.

Date.	Division.	Reading of Micrometer For Division. r	d	For Star. r	d	Nominal Second's of Micrometer in Run over 3'.	Apparent Z.D. (Uncorrected for Refraction.) °	′	″	Mean Z.D. for Jan. 0. °	′	″
1789.	′											
Jan. 18	12	2	5·2	7	15·7	181·3	0	14	24·46	0	14	18·19
	15	8	24·5									
30	15	8	14·7	7	9·4	(181·5)			27·97			18·24
Feb. 1	12	1	22·3	7	11·6	181·5			30·05			19·80
	15	8	14·8									
2	12	1	21·4	7	10·2	182·8			28·49			17 98
	15	8	15·2									
4	12	1	23·9	7	15·4	183·0			30·98			19·97
	15	8	17·9									
5	12	1	24·6	7	17·2	183·4			31·73			20·48
	15	8	19·0									
8	12	1	24·0	7	16·7	183·2			32·00			20·06
	15	8	18·2									
9	12	1	25·0	7	17·9	183·1			32·28			20·12
	15	8	19·1									
10	12	1	24·8	7	18·3	183·5			32·53			20·16
	15	8	19·3									
						Sector E.						
1789.												
Feb. 12	12	8	7·5	2	10·9	182·3	0	14	36·60	0	14	23·81
	15	1	14·2									
15	12	8	3·9	2	5·3	183·2			37·80			24·43
	15	1	9·7									
						Sector W.						
1790.												
Oct. 15	12	9	9·7	13	17·1	181·6	0	13	54·38	0	14	19·43
	15	16	2·3									
16	12	9	13·7	13	21·1	181·0			54·77			19·69
	15	16	5·7									
Nov. 4	12	9	6·7	13	19·0	182·2			58·85			20·46
	15	15	26·9									
5	12	9	6·2	13	18·3	182·4	0	13	58·52			19·90
	15	15	26·6									
13	12	9	3·1	13	17·3	182·3	0	14	0·66			20·13
	15	15	23·4									
15	12	9	5·7	13	20·9	183·5			0·85			19·80
	15	15	27·2									
16	12	9	5·7	13	21·8	183·1			2·00			20 69
	15	15	26·8									

Date.	Division.	Reading of Micrometer For Division.	For Star.	Nominal Seconds of Micrometer in Run over 3′.	Apparent Z.D. (Uncorrected for Refraction.)	Mean Z.D. for Jan. 0.
1790	′	r d	r d		° ′ ″	° ′ ″
Nov. 27	12	9 3·7	13 22·4	182·1	0 14 5·24	0 14 20·61
	15	15 23·8				
*Dec. 6	12	16 26·7	3 18·8	183·0	5·02	17·69
	15	5 20·7				
12	12	10 22·0	15 20·0	184·3	9·90	20·57
	15	17 17·3				
20	12	0 6·3	5 5·8	181·7	13·24	20·81
	15	6 26·0				
21	12	7 19·5	12 20·2	182·9	13·55	20·78
	15	14 13·4				
†22	12	17 24·4	4 23·9	181·4	13·46	20·34
	15	6 16·8				
28	12	0 0·0	5 4·1	181·9	17·65	22·43
	15	6 19·9				
30	12	7 3·2	12 7·3	182·7	17·04	21·12
	15	13 23·9				
			Sectcr E.			
1791.						
Jan. 4	12	6 19·4	1 9·0	182·4	0 14 23·49	0 14 26·65
	15	17 26·0				
7	12	8 18·6	3 9·8	181·2	22·85	24·93
	15	1 26·4				
14	12	3 8·3	15 23·7	181·0	25·79	25·54
	15	14 16·3				
19	12	10 5·0	4 18·7	181·2	27·32	25·48
	15	3 12·8				
20	12	10 6·6	4 19·6	181·9	27·44	25·28
	15	3 13·7				
27	12	14 7·0	8 17·6	181·4	30·23	26·00
	15	7 14·6				
31	12	4 2·0	16 12·7	181·1	30·38	25·05
	15	15 9·9				
Feb. 2	12	15 20·4	10 3·7	181·1	30·78	24·93
	15	9 1·3				

* 1790 December 6, the reading of the micrometer has been diminished from $17^r\ 26^d{\cdot}7$ to $16^r\ 26^d{\cdot}7$.

† 1790 December 22, the reading of the micrometer has been diminished from $5^r\ 23^d{\cdot}9$ to $4^r\ 23^d{\cdot}9$.

Date. 1791	Division.	Reading of Micrometer For Division. r d	For Star. r d	Nominal Seconds of Micrometer in Run over 3′.	Apparent Z.D. (Uncorrected for Refraction.) ° ′ ″	Mean Z.D. for Jan. 0. ° ′ ″
Feb. 8	12	15 17·7	10 0·0	181·1	0 14 31·77	0 14 24·45
	15	8 25·6				
17	15	8 25·0	9 24·2	(181·8)	34·01	24·85
	15	8 24·5				
23	15	8 24 6	9 23·1	(181·8)	33·91	23·77
	15	8 22·9				
28	12	15 19·3	9 25·7	182·5	33·47	22 68
	15	8 25·8				
		Sector E.				
Sept. 10	12	5 3·3	0 20·1	181·9	0 13 56·97	0 14 25·06
	15	16 10·4				
11	12	5 5·5	0 21·1	183·2	57·31	25·46
	15	16 11·3				
12	12	5 5·4	0 23·1	179·7	57·50	25·70
	15	16 14·7				
13	12	5 7·0	0 21·7	183·1	58·26	26·51
	15	16 12·9				
14	12	5 6·2	0 20·8	181·7	59·27	27·56
	15	16 13·5				
15	12	5 7·5	0 23·1	181·2	58·61	26·93
	15	16 15·3				
16	12	5 7·0	0 20·8	181·0	60·53	28·88
	15	16 15·0				
18	12	5 9·0	0 24·5	181·0	58·84	27·23
	15	16 17·0				
25	12	5 8·7	0 24·0	180·5	59·37	27·73
	15	16 17·2				
		Sector W.				
Sept. 26	12	5 25·1	10 6·4	182·9	0 13 54·46	0 14 22·79
	15	12 19·0				
28	12	5 25·0	10 5·6	182·3	54·14	22·40
	15	12 18·3				
29	12	6 0·4	10 7·3	182·1	53·58	21·79
	15	12 20·5				
30	12	6 0·0	10 7·7	182·4	54·18	22·34
	15	12 20·4				

Date. 1791	Division.	Reading of Micrometer For Division. r	d	For Star. r	d	Nominal Seconds of Micrometer in Run over 3′.	Apparent Z.D. (Uncorrected for Refraction.) ° ′ ″	Mean Z.D. for Jan. 0. ° ′ ″
Oct. 1	12	6	0·3	10	7·9	183·0	0 13 53·70	0 14 21·81
	15	12	21·3					
5	12	5	25·2	10	5·3	182·3	53·65	21·48
	15	12	18·5					
12	12	5	24·9	10	5·5	182·4	54·08	21·19
	15	12	18·3					
13	12	5	25·5	10	6·6	182·2	54·70	21·68
	15	12	18·7					
15	12	5	24·0	10	4·5	182·7	53·79	20·51
	15	12	17·7					
17	12	5	23·1	10	3·9	181·1	55·10	21·53
	15	12	15·2					
18	12	5	19·6	10	0·8	180·9	55·62	21·90
	15	12	11·5					
19	12	5	20·2	10	1·6	181·8	55·25	21·37
	15	12	13·0					
				Sector E.				
Oct. 23	12	14	23·4	10	11·0	178·5	0 14 1·41	0 14 26 84
	15	8	6·9					
24	12	14	22·5	10	7·8	180·6	2·29	27·54
	15	8	3·9					
27	12	14	24·8	10	9·3	182·1	2·08	26·75
	15	8	4·7					
Nov. 7	12	15	2·2	10	10·3	181·3	5·99	28·16
	15	8	9·9					
18	12	14	24·4	10	5·4	180·3	6·79	25·95
	15	8	6·1					
29	12	14	21·2	9	25·0	179·2	11·79	27·54
	15	8	4·0					
Dec. 28	12	14	22·1	9	18·7	180·1	18·32	23·72
	15	8	4·0					

On the Angular Distance of Two Stars in the Pleiades suitable for Determining the Value of a Micrometer Screw. By Professor H. H. Turner, M.A., B.Sc.

1. The following discussion was made in response to a request by Mr. H. F. Newall in 1895 February. He wrote: "I want to determine as accurately as possible the value of my micrometer screw, and have measured two stars in the *Pleiades* about 300″ apart. . . . Can you give me their accurate difference of Right Ascension? To determine this by transits would involve much labour." It is possible that the results of the investigation may be useful to others also.

2. A long series of photographs of the *Pleiades* was taken at this observatory in 1892–93, and some measures on three of these plates have been published (*Monthly Notices*, liv. p. 489). To give a better determination, however, twelve additional plates were measured, as described below.

3. The stars used by Mr. Newall are those numbered 33 and 44 by Elkin.* His numeration will be hereinafter adopted. They are numbered 34 and 45 by Jacoby.†

The second, but not the first, was measured by Bessel in 1840, and called Anon. 24; and again by Pritchard (*Mem. R.A.S.*, vol. xlviii.); but neither by Ambronn, of Göttingen, in 1894. Adopting the precessions and secular variations given by Elkin to bring up both his own and Jacoby's places to 1892·0 (the equinox used for the Oxford photographic measures), we find the differences of Right Ascension and Declination are as follows:—

	R.A.	Decl.
Jacoby	+4′ 50″·13	+44″·74
Elkin	+4 49·80	+44·75

The Oxford measures already published were made on plates taken on 1892 December 12, 13, and 1893 February 10 (*Monthly Notices*, liv. p. 489), and are expressed in rectangular coordinates on a tangent plane to the celestial sphere at *Alcyone*. It will be convenient to use these coordinates in what follows. The coordinates of the two stars on this plane with axes oriented for 1892·0, and expressed in *réseau* intervals (of 5′ of arc) are, according to Elkin's measures:—

* *Transactions of the Yale University Observatory*, vol. i., part 1, pp. 86 and 87.

† *The Rutherfurd Photographic Measures of the Group of the Pleiades. Observatory of Columbia College.* New York, 1892.

	Star.	ξ	η
	33	−0·8864	+2·0502
	44	−0·0034	+2·1990
Diff.	(44–33)	+0·8830	+0·1488

Jacoby's results, as well as those which follow, may be exhibited as corrections to these differences. The corrections indicated by Jacoby's measures in 1873·0 are—

ξ	η
+·0010	·0000

The corrections indicated by the three Oxford photographs are—

Plate.	ξ	η
252	+·0006	+·0013
259	−·0025	+·0007
294	+·0017	−·0001
Mean	−·0001	+·0006

There seems, therefore, no doubt that the relative proper motion of the two stars is very small, though further measures are desirable.

4. Accordingly on 1895 February 16 I measured the images of eight stars (two images each) on each of eight plates. Two of the stars were the above pair, and the other six were distributed so as to give a good determination of the constants of the plates. The micrometer used was that arranged with a scale in the eye-piece, described in *Monthly Notices*, lv. p. 102. The corrections to the measures due to errors of orientation, &c., of the plate affect the two close stars in question by nearly the same amount; and hence the details of the corrections need not be here given. The method of reduction adopted (by rectangular coordinates) is fully described in *Monthly Notices*, liv. p. 489, and again in lv. p. 102.

5. In Table I., the fifth and ninth columns give the actually measured distances between the stars (parallel to the *réseau* lines, and expressed in *réseau* intervals) for the two images on each plate. Each distance is the difference between two single readings of the eye-piece scale when placed centrally on each star in turn. The third figure is estimated. The next columns give the correction for orientation to the "mean plate" as determined from the four stars numbered by Elkin 19, 41, 43, and 60; and after applying this correction the results, given in columns 7 and 11, are strictly comparable. The differences from the means shown in columns 8 and 12 are not larger than is to be expected, considering that the last digit is estimated, or rather is the difference of two estimations. The errors may be treated as accidental.

TABLE I.

Plate.	Date of Exposure.	Tel. E or W. of pier.	Hour Angle West.	Measured $x_{44}-x_{22}$.	Correction.	Corrected Difference.	Excess over Mean.	Measured $y_{44}-y_{22}$.	Correction.	Corrected Difference.	Excess over Mean.
	1892.		h								
218 (1)	Oct. 17	W.	−3·4	0·890	...	·890	−·001	·151	·000	·151	+·001
(2)			−3·3	·893	...	·893	+·002	·151	·000	·151	+·001
243 (1)	Nov. 29	W.	−0·5	·894	−·001	·893	+·002	·145	+·004	·149	−·001
(2)			−0·3	·895	−·001	·894	+·003	·145	+·003	·148	−·002
244 (1)	Nov. 29	W.	0·0	·891	...	·891	·000	·148	+·003	·151	+·001
(2)			+0·2	·890	...	·890	−·001	·146	+·003	·149	−·001
263 (1)	Dec. 23	W.	−1·3	·892	...	·892	+·001	·148	+·001	·149	−·001
(2)			−1·2	·891	...	·891	·000	·150	+·001	·151	+·001
	1893.										
280 (1)	Jan. 14	W.	+0·1	·889	+·001	·890	−·001	·155	−·006	·149	−·001
(2)			+0·3	·890	+·001	·891	·000	·156	−·006	·150	·000
291 (1)	Feb. 8	E.	+1·5	·889	+·001	·890	−·001	·152	−·004	·148	−·002
(2)			+1·6	·890	+·001	·891	·000	·154	−·004	·150	·000
294 (1)	Feb. 10	W.	+2·1	·890	...	·890	−·001	·149	+·002	·151	+·001
(2)			+2·1	·888	...	·888	−·003	·149	+·002	·151	+·001
306 (1)	Mar. 4	E.	+2·8	·891	...	·891	·000	·149	·000	·149	−·001
(2)			+2·9	·890	...	·890	−·001	.151	·000	·151	+·001
					Mean	·8909			Mean	·1499	

6. Proceeding now to compare the "mean plate" with the theoretical tangent-plane at *Alcyone*, we use the "standard coordinates" ξ and η of the same stars, as given in *Monthly Notices*, liv. p. 494; and with the notation of that paper we find

$$a = e = +\cdot0078,\ b = -d = \cdot0000 \text{ sensibly},$$

the values of a and e agreeing well with those found in the above paper, which is a satisfactory indication of the permanence of the scale-value on the plates.

The differences thus become

$$+\cdot8840 \text{ and } +\cdot1491$$

as compared with the

$$+\cdot8830 \text{ and } +\cdot1488$$

of Elkin, giving corrections to Elkin of

$$+\cdot0010 \text{ and } +\cdot0003.$$

7. It may be objected that these measures are made by a comparatively rough method; and this is to some extent true. On the other hand eight different plates were measured and two independent images on each, and the agreement of the different results is fairly satisfactory. Personally, having had some considerable experience of this particular form of micrometer, I am inclined to estimate its capabilities distinctly high; but, as others may not yet agree in this estimate, the following independent investigation was made for the x-coordinates.

Mr. G. F. H. Smith, of New College, Oxford, using the micrometer made by Messrs. Troughton & Simms for the late Professor Pritchard, which is provided with an excellent steel screw ($1^{rev} = 1^{mm} = 1'$ approx.), measured the difference of the x coordinates of the two stars 33 and 44 on twelve plates, eight of which were the same as the above. The plates were carefully oriented, so that the direction of measurement was parallel to one set of *réseau* lines, and the corrections for orientation already made use of were thus again available in the case of eight plates. For the others corrections were determined by a similar method. The only new constant required is the value of one revolution of the screw in terms of a *réseau* interval.

8. *Uniformity of Screw.*—The total available length of the screw is about 25 revs. Seven sets of comparisons of different portions of the screw with *réseau* intervals give the following results. It should be remarked that the eye-piece is fixed and the plate bodily moved by the screw, so that a change of focal distance does not affect the measures.

Value of one *réseau* interval in terms of revolutions of screw:

0^r —— 5^r	—— 10^r	—— 15^r	—— 20^r
$5^r\cdot0039$	$5\cdot0004$	$4\cdot9977$	$4\cdot9966$

There is apparently, therefore, a gradual change in the value of 1^{rev} as we proceed along the screw. In the star-measures care was taken always to use the same part of the screw (viz. the portion $5^r - 10^r$) for measuring the distance between the stars 33 and 44; or, in exceptional cases, to apply the corresponding correction.

9. *Value of* 1^{rev} *of Screw.*—This is not assumed to remain constant, since the expansion of the film is probably not the same as that of the screw. At the time of measuring the stars, three or four *réseau* intervals were measured with the screw also. When other parts of the screw than the portion $5^r - 10^r$ were used for either stars or *réseau* intervals, the measures were corrected according to the results of the last paragraph. The mean value of a revolution of the screw, thus found at the time, has been used to reduce the star-measures to *réseau* intervals. The measures are thus expressed in terms of the average *réseau* interval, which is the unit employed in connecting the measures on the plate with Elkin's measures in arc, according to the methods explained above.

10. In the following table, column 5 gives the measure in *réseau* intervals, assuming 5^{rev} of the screw to be equal to one interval. Column 6 gives the correction for runs as in the last paragraph; column 7 the corrections for orientation, &c., found as above, and supplied by Mr. G. F. H. Smith were necessary; column 8 the finally corrected distance; and column 9 the residuals.

TABLE II.

Plate.	Date of Exp.	Tel. W. or E. of pier.	Hour Angle. h	Measure.	Corr. for Runs.	Corr. for Orientation, &c.	Corrected Measure.	Excess over Mean.
218	Oct. 17	W.	−3·4	·8910	−·0011	−·0074	·8825	−·0009
243	Nov. 29	W.	−0·5	·8909	−·0005	−·0072	·8832	−·0002
244	„ 29	W.	0·0	·8911	−·0002	−·0074	·8835	+·0001
251	Dec. 12	W.	−2·6	·8912	−·0004	−·0070	·8838	+·0004
254	„ 12	W.	−1·5	·8908	−·0005	−·0066	·8837	+·0003
263	„ 23	W.	−1·3	·8915	−·0008	−·0070	·8837	+·0003
280	Jan. 14	W.	+0·1	·8914	−·0007	−·0058	·8849	+·0015
281	„ 14	W.	+0·7	·8900	−·0005	−·0070	·8825	−·0009
291	Feb. 8	E.	+1·5	·8902	−·0005	−·0062	·8835	+·0001
294	„ 10	W.	+2·1	·8899	−·0003	−·0074	·8822	−·0012
296	„ 14	W.	+0·9	·8900	−·0002	−·0066	·8832	−·0002
306	Mar. 4	E.	+2·8	·8907	−·0004	−·0068	·8835	+·0002
						Mean	·8834	

The mean value thus gives a correction to Elkin of +·0064, as compared with +·0010 from the former measures and −·0001

from those previously published. The results for the different plates, being each the mean of several readings, naturally accord more closely than before.

11. As one or two of the residuals seem large, Mr. G. F. H. Smith repeated some of his measures; but it seemed clear that the discrepancies were accidental, and nothing is gained by adding these few new measures to the above.

12. Collecting all the results we thus have the following corrections to Elkin's heliometer measures from photographic measures

TABLE III.

Measurer.	Place.	Date of Photos.	Corrections to ξ	Corrections to η
Rutherfurd and Jacoby	New York	1873·0	+·0010	·0000
(Elkin	Yale College	1885·0	·0000	·0000)
Bellamy	Oxford	1893·0	−·0001	+·0006
Turner	,,	,,	+·0010	+·0003
Smith	,,	,,	+·0004	...

Combining the Oxford results with equal weight we should obtain proper motions of −·00003 and +·00001 in ξ and η respectively from the extreme measures. Applying these to the two earlier results we get for the simple mean of New York, Yale, and Oxford, at epoch 1893·0,

+·0002 and +·0001,

or in the more familiar unit of seconds of arc

in R.A. +0″·06 and in Decl. +0″·03,

with the annual increments

−0″·009 and +0″·003 respectively.

13. It would thus appear that, so far as these measures indicate, Elkin's distance between these stars does not at the present time require a correction of so much as 0″·1. The following may be given as the definitive value of the distance in arc of a great circle, if it is preferred to use this instead of the difference of R.A.

$$268''.71 - 0''.008\,(t - 1893.0).$$

A General Method for Facilitating the Solution of Kepler's Equation by Mechanical Means. By T. J. J. See, A.M., Ph.D. (Berlin).

The standard works on planetary motion, such as Gauss' *Theoria Motus*, Oppolzer's *Bahnbestimmung*, and Watson's *Theoretical Astronomy*, give methods for solving Kepler's equation which are very satisfactory when the eccentricity of the orbit is small, and also when this element is large, as in the case of most of the periodic comets. When the eccentricity is small, an expansion in series, usually by Lagrange's Theorem, enables us to find the eccentric anomaly with the desired facility. The series frequently employed has the form

$$E_0 = M + e'' \sin M + e''\left(\frac{e}{2}\right) \sin 2M + \ldots .$$

To the approximate value E_0, obtained from a few terms of this series, we apply a correction resulting from the expansion by Taylor's Theorem :

$$E = E_0 + \frac{dE_0}{dM_0} dM_0 + \ldots .$$

The equation of Kepler gives

$$\frac{dM_0}{dE_0} = 1 - e \cos E_0 ;$$

and since

$$dM_0 = M - M_0,$$

we find two terms of the series to be

$$E = E_0 + \frac{M - M_0}{1 - e \cos E_0}.$$

Successive applications of this formula will readily yield the true value of the eccentric anomaly. But when the eccentricity is considerable the expansion in series fails to converge with the desired rapidity. On the other hand, when the orbits differ but little from parabolas, the solution can be readily found by means of special tables, such as those given by Gauss, Watson, and Oppolzer.

It is very remarkable that among the many solutions of Kepler's equation discovered by mathematicians there is not one, so far as I am aware, which has come into general use among astronomers that is applicable to ellipses of all possible eccentricities. The method to which I desire to call attention is a modification of the graphical method given by Klinkerfues,* and originally proposed by Dubois.†

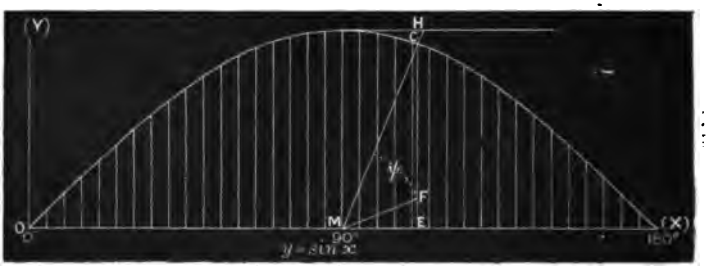
* *Theoretische Astronomie*, p. 17.

† *Astronomische Nachrichten*, No. 1404.

Suppose we construct, on a convenient scale, a semicircumference of the curve of sines, $y = \sin x$. In practice it is desirable to use millimetre paper, and a convenient scale is obtained by taking one degree of the arc as five millimetres, so that the scale may easily be read to 0°·1. The origin of the arc is taken at the origin of coordinates; and as the scale along the axis of abscissæ extends from 0° to 180°, it will have a length of 90 centimetres.

In the figure let OM represent the mean anomaly, and suppose from M we draw a right line making an angle Ψ with the axis of abscissæ, the angle Ψ being defined by the equation

$$\tan \Psi = \frac{1}{e}.$$



Let the abscissa of the point C, determined by the intersection of the right line MC with the sine curve, be denoted by E. Then we evidently have

$$OE - ME = OM.$$

Thus, denoting the arc OE by E, and observing that $e \sin \Psi = \cos \Psi$, we find that $e \sin \Psi = ME$, the radius in case of sin Ψ being such that sin Ψ is always equal to sin E.

Hence we get

$$OE - ME = OM,$$

or

$$E - e \sin E = M,$$

which is the equation of Kepler.

Therefore we conclude that if for an orbit of given eccentricity we construct a triangle CME (in practice this may be made of cardboard) and apply the vertex M of the triangle to the successive mean anomalies, the base coinciding with the x axis, the intersection of the hypothenuse with the curve of sines will give at once abscissæ which are the corresponding eccentric anomalies. Any actual diagram such as we have described will be subject to slight inaccuracies of construction owing to the transcendental nature of the sines, and hence we cannot obtain solutions of absolute precision. But it is entirely possible to get approximate solutions exact to 0°·1, and this work

can be done with the greatest rapidity. It is merely necessary to slide the base of the triangle along the x axis, placing the vertex M at the points corresponding to the different values of the mean anomaly, and reading off the corresponding eccentric anomalies.

This triangle device is rendered possible by virtue of the fact that Ψ is constant in $\tan \Psi = \frac{1}{e}$; and we may observe that in case of elliptic orbits the angle Ψ can only vary from 45° in case of a parabola to 90° in case of a circle. This method is therefore directly applicable to ellipses of every possible eccentricity, and the accuracy of the solution is always substantially the same. In case of parabolic motion, however, the method fails, since when $\Psi = 45°$ the hypothenuse MC is tangent to the sine curve at the origin. But for $e < 1$ the hypothenuse MC intersects the curve $y = \sin x$, and the intersection will be well defined except when e approaches unity and M is very small. In such cases it is best to use the Special Tables or the Theory of Parabolic Motion. Solutions exact to 0°·1 are often sufficient in the present state of double-star observation, and we readily see how great is the practical value of this method in comparing a long series of observations with a given set of elements. One hundred approximate solutions of Kepler's Equation, accurate to 0°·1, may be obtained by this method in less than half an hour; while if e lies between 0·35 and 0·85 a skilled computer could probably not obtain the same results by the ordinary method in less than a day. Thus the time and labour required for this work is much diminished, and it is clear that the chances of large error are correspondingly reduced.

If a curve of sines were engraved on a metallic plate it would be an easy matter to devise a movable protractor which could be set at any angle; such a piece of apparatus would serve for every possible elliptic orbit, and would last for an indefinite time. Considering the immense labour devolving upon astronomers in the computation of the motion of the heavenly bodies, it would seem that such a labour-saving device might be advantageously employed in the offices of the astronomical ephemerides. However, as several astronomers have prepared tables for facilitating the solution of Kepler's Equation in case of orbits which are not very eccentric, such an apparatus would be useful chiefly in work on the more eccentric asteroids, the double stars, and periodic comets. In dealing with the motions of these bodies the labour saved would be very considerable, and we might hope that the apparatus here suggested would come into actual use. But in case this instrument of precision could not be successfully manufactured, owing to its limited commercial use, it is easy for a working astronomer to construct a curve of sines on millimetre paper. This can be mounted on a suitable wooden board, and a triangle of cardboard will give the solutions of Kepler's Equation for any given orbit.

Klinkerfues has shown how we may use the diagram to correct our approximate values of E with great rapidity. Suppose we take a pair of dividers and set them to the value of e on the scale of the sine curve; then, placing one foot at M, let us describe a circular arc cutting the ordinate CE in F. The line $MF=e$, $ME=e \sin E$, and $FE=e \cos E$. Hence

$$HF = 1 - e \cos E = \frac{dM}{dE}.$$

The exact value of M is given, and since

$$M_0 = E_0 - e \sin E_0 = OE - ME,$$

the value of $dM_0 = M - M_0$ is at once obtained. Then we have

$$\Delta E_0 = \frac{M - M_0}{1 - e \cos E_0},$$

which gives a second approximation to the true value of the eccentric anomaly. This correction can be applied with great rapidity, since the dividers will always have the same setting for a given eccentricity.

Thus, while the graphical method, originally proposed by Dubois and afterwards improved by Klinkerfues, has been suggested many years ago, it does not appear that it has ever come into actual use; and I have therefore thought it worthy of the attention of astronomers, particularly in the modified form here proposed. For it seems clear that a general method for solving Kepler's Equation by mechanical means is an urgent *desideratum* of astronomy, owing to the large number of orbits requiring investigation and the wide range of their eccentricities.

In computing the motions of double stars, where the eccentricities have all values from 0·1 to 0·9, I have found this device of the greatest service. It will be almost, if not quite, equally important in case of the periodic comets and the asteroids. But in dealing with comets and planets, where we desire very exact solutions of Kepler's Equation, I would suggest that the approximate values of E should be read off, and one correction applied in the manner here indicated; a second correction to be *computed* by the formula

$$\Delta E_0' = \frac{M - M_0'}{1 - e \cos E_0'},$$

where M_0', E_0' are the first corrected values of E_0, or

$$E_0 + \frac{M - M_0}{1 - e \cos E_0}$$

will probably give the true values of the eccentric anomaly

$$E = E_0' + \Delta E_0',$$

within a small fraction of a second of arc. Thus practically all *computation* is done away with, except a single correction which would be required in order to insure the accuracy desirable in planetary and cometary ephemerides.

The University of Chicago:
1895 May 24.

On a Catalogue of Stars in the Calendarium of Mohammad Al Achsasi Al Mouakket. By E. B. Knobel.

I have lately obtained a 17th century Arabic MS. of a calendarium by Al Achsasi—a name that is not to be found in the usual sources of information about Oriental astronomers, such as D'Herbelot, *Bibliothèque Orientale*; Casiri, *Bibliotheca Escurialensis*; Houzeau, *Bibliographie de l'Astronomie*; the British Museum, the Bodleian, and the Leyden Libraries, &c. But fortunately I have found the name of the author and the title of the treatise in the catalogue of the Khedive's library at Cairo, but without any date.

The author, Mohammad Al Achsasi Al Mouakket, was Sheikh of the Grand Mosque at the College at Cairo, and surnamed Al Mouakket from his functions of regulating the times and the hours at the mosque. He derived his name "Achsasi" from a village so called, which I find existed in the province of Fayoum in Egypt. The MS. was therefore clearly written at Cairo. Its title is "Durret Al Muddiah Fih Al Aamal Al Shamsiah" (Pearls of brilliance upon the solar operations).

The MS. is unfortunately not complete, but it contains tables of the position of the Sun for each day of the Coptic and Syriac months, a list of cities in Arabia and Northern Africa, a concordance of Coptic and Mohammadan years, a catalogue of stars, a complete almanac of the Coptic year, and some other astronomical tables.

The catalogue gives the positions of 112 stars in right ascension and declination; and as it presents some points of interest I have translated this portion of the MS. as perhaps worthy of publication.

Prior to modern European astronomy it was unusual to give the positions of stars in right ascension and declination, and in the few cases where this was done by Oriental astronomers the right ascensions, designated by the term al mataliâ "coascendants," were always calculated from the first point of Capricornus —the solstitial colure, as we find in the present instance.

In investigating this MS. it is natural to suspect that it is a copy of the Calendarium of Al Tizini, who also bore the designation of "Al Mouakket," and who published his tables at Damascus in 1534. Al Tizini's catalogue of 302 stars was translated by

Hyde and published by him in 1665 as an appendix to his translation of Ulugh Beg. I have no doubt whatever that Al Achsasi based his tables upon those of Al Tizini; but the catalogue of the former contains a few stars not given by the latter, and also some differences in the descriptions of the stars, which indicate that it may not be simply a copy reduced to a later epoch.

The MS. is fairly written, but absolutely without vowels and very deficient in diacritical points, and there are numerous mistakes in words and figures.

The catalogue in the MS. gives the names of the stars, the right ascension, declination and magnitudes, and a column headed by a word which signifies the *nature* of the star. Against some stars are affixed certain letters, which probably indicate the Sun or some of the planets, and are clearly of astrological significance. Similar columns are to be found in the editions of Ptolemy's Catalogue published in the Alfonsine tables of 1483, the Trapezuntius Ptolemy of 1528, Bartsch's Planisphærium Stellatum, and many other mediæval works.

The epoch is not given, but the positions of the stars seem to be for about the year 1650, and on this assumption I append a comparison of the right ascensions of twenty-four stars in Al Achsasi and Al Tizini (reduced to 1650) with the correct positions for that epoch derived from Dr. Danckworth's catalogue published in the *Vierteljahrsschrift* for 1881.

In the catalogue I have given the Arabic names with the Latin translation and the modern designation of the stars.

No.	Arabic Name.	Modern Name.	Right Ascension.	Declination.	Region.	Mag.
1	Rabah al Waridah * *Quarta τοῦ al Warida*	η Sagittarii	0 41	36 5	S	3
2	Rai al Naaim *Pastor Struthionum*	λ Sagittarii	1 56	26 29	...	4
3	Aoul al Sadirah * *Prima τοῦ al Sadirah*	ϕ Sagittarii	6 0	26 27	S	1
4	Al Nesr al Waki * *Vultur Cadens*	α Lyræ	6 53	38 30	N	...
5	Thanih al Sadirah *Secunda τοῦ al Sadirah*	σ Sagittarii	8 44	26 48	S	3
6	Dzaneb al Heiyet * *Cauda Serpentis*	θ Serpentis	9 44	3 11	N	...
7	Thalath al Sadirah *Tertia τοῦ al Sadirah*	ζ Sagittarii	10 31	30 25	S	3
8	Nir al Beldat * *Lucida Oppidi*	π Sagittarii	11 18	21 55	S	3
9	Dzaneb al Tair *Cauda (Vulturis) Volantis*	ζ Aquilæ	12 27	13 0	N	3
10	Djenubi Menkib al Nesr *Australior Humerus Vulturis*	δ Aquilæ	17 21	2 27	N	3

No.	Arabic Name.	Modern Name.	Right Ascension.	Declination.	Region.	Mag.
11	Menchir al Dedjadjet *Rostrum Gallinæ*	β Cygni	20 26	26 21	N	2
12	Menkib al Nesr *Humerus Vulturis*	γ Aquilæ	22 32	9 36	N	2
13	Al Nesr al Tair * *Vultur Volans*	α Aquilæ	23 46	30 29	N	2
14	Unuk al Ghyrab * *Collum Corvi* (i.e., *Vulturis*)	β Aquilæ	25 50	5 41	N	3
15	Thanih Ras al Akab *Secunda Capitis Vulturis*	θ Aquilæ	28 19	3 6	S	3
16	Shimalih Saad al Dzabihh * *Borealior Fortunæ Immolatoris*	α Capricorni	30 28	13 33	S	3
17	Sadr al Dedjadjet * *Pectus Gallinæ*	γ Cygni	33 20	29 0	N	3
18	Dzaneb al Delphin *Cauda Delphini*	ε Delphini	35 35	10 1	N	4
19	Nir Saad Bula * *Lucida Fortunæ Dissipantis*	ε Aquarii	36 43	11 12	S	4
20	Nir Saad al Shaoud * *Lucida Fortunæ Fortunarum*	β Aquarii	49 2	30 23	S	2
21	Thanih Saad al Saaoud *Secunda Fortunæ Fortunarum*	ξ Aquarii	50 36	9 40	S	3
22	Fam al Feras *Os Equi*	ε Pegasi	52 38	8 33	N	3
23	Aoul al Achbiya * *Prima Tabernaculorum*	γ Aquarii	61 4	3 18	S	4
24	Wasat al Achbiya *Media Tabernaculorum*	π Aquarii	62 0	1 18	S	4
25	Achr al Achbiya *Postrema Tabernaculorum*	ζ Aquarii	64 40	2 0	S	3
26	Nir Saad al Bahaim * *Lucida Fortunæ Ferarum*	ζ Pegasi	66 21	8 30	N	3
27	Al Dsefadah al Aoul *Rana Prima*	α Piscis Australis	70 0	33 48	S	1
28	Shimalih al Mukdim * *Borealior*	β Pegasi	72 6	25 0	N	1
29	Djenubi al Mukdim *Australior*	α Pegasi	72 36	13 20	N	2
30	Fam al Samkat *Os Piscis*	β Piscium	75 1	1 0	N	4
31	Keff al Salsulat * *Manus Catenatæ*	ι Andromedæ	81 25	4 33	N	4
32	Dzaneb al Samkat *Cauda Piscis*	ω Piscium	85 36	4 32	N	...
33	Shimalih al Muchir * *Borealior*	δ Pegasi	88 0	26 13	N	2

No.	Arabic Name.	Modern Name.	Right Ascension.	Declination.	Region.	Mag.
34	Djenubi al Muchir *Australior*	γ Pegasi	89 20	14 32	N	2
35	Al Dsefadah al Thanih * *Rana Secunda*	β Ceti	96 55	18 0	S	3
36	Al Rascha * *Funis*	β Andromedæ	102 35	33 13	N	2
37	Aoul al Naamet * *Prima Struthionum*	η Ceti	103 0	11 30	S	2
38	Thanih al Naamet * *Secunda Struthionum*	θ Ceti	107 0	10 15	S	2
39	Thalath al Naamet * *Tertia Struthionum*	τ Ceti	112 0	18 30	S	2
40	Al Djedi * *Capra*	α Ursæ Minoris	105 17	?	N	2
41	Ras al Mathlath *Caput Trianguli*	α Trianguli	113 20	26 13	N	...
42	Rabah al Naamet *Quarta Struthionum*	ζ Ceti	114 35	12 0	...	2
43	Shimalih al Sheratein * *Borealior Signorum*	β Arietis	114 26	18 0	N	2
44	Khamis al Naamet * *Quinta Struthionum*	γ Andromedæ	115 36	40 8	N	3
45	Al Natih *Cornu*	α Arietis	116 0	20 30	N	2
46	Nir al Botein * *Lucida Ventris*	δ Arietis	136 21	23 0	N	4
47	Keff al Djezma * *Manus Truncata*	α Ceti	131 26	2 11	N	4
48	Achr al Nahr *Postrema Fluminis*	θ Eridani	132 0	41 0	S	1
49	Al Thaur al Thureiya ? *Pleiadum*	η Tauri	141 12	22 0	N	4
50	Sadr al Thaur *Pectus Tauri*	λ Tauri	145 37	11 3	N	2
51	Aoul al Debaran * *Prima τοῦ al Debaran*	γ Tauri	150 0	14 40	N	2
52	Nir al Debaran * *Lucida τοῦ al Debaran*	α Tauri	156 21	21 0	N	...
53	Wasat Taj al Djauza *Media Tiara Gigantis*	π Orionis	158 0	7 21	N	4
54	Rabah al Nahr *Quarta Fluminis*	ω Eridani	159 0	6 30	S	4
55	Al Aiouk * ?	α Aurigæ	162 0	44 30	N	4
56	Rijil al Djauza * *Pes Gigantis*	β Orionis	164 0	21 3	S	1

No.	Arabic Name.	Modern Name.	Right Ascension.	Declination.	Region.	Mag.
57	Kurn al Thaur al Shimalih *Cornu Boreale Tauri*	β Tauri	165 50	28 0	N	2
58	Menkib al Djauza al Aisr *Humerus Sinister Gigantis*	γ Orionis	166 5	5 32	N	2
59	Aoul al Nazhm *Prima Lineæ Margaritarum*	δ Orionis	168 46	1 11	S	2
60	Ras al Djauza *Caput Gigantis*	λ Orionis	170 0	9 36	N	Neb.
61	Rekbah al Djauza al Yemeniat* *Genu Dextrum Gigantis*	κ Orionis	173 0	10 11	S	2
62	Mirzem al Yemeniat * ?	β Canis Majoris	183 0	17 45	S	3
63	Nir al Henat * *Lucida rotî al Henat*	γ Geminorum	184 0	36 0	N	4
64	Al Shira al Yemeniat * ?	α Canis Majoris	187 40	15 43	S	4
65	Aoul al Adzari * *Prima Virginum*	ε Canis Majoris	191 0	29 0	S	4
66	Thanih al Adzari *Secunda Virginum*	o^2 Canis Majoris	193 0	24 5	S	2
67	Thalath al Adzari * *Tertia Virginum*	δ Canis Majoris	194 0	28 31	...	2
68	Mirzem al Ghomeisa ?	β Canis Minoris	196 40	9 0	N	4
69	Aoul al Dzira * *Prima Brachii*	α Geminorum	197 43	?	N	1
70	Al Shira al Shamiyat ?	α Canis Minoris	200 0	6 20	N	1
71	Muekher al Dzira *Posterior Brachii*	β Geminorum	201 0	38 46	N	1
72	Lisan al Shudja * *Lingua Hydri*	δ Hydræ	212 0	6 0	N	4
73	Al Nethra * ?	ε Cancri	215 0	20 49	N	Neb.
74	? Al Shudja * ? *Hydri*	ζ Hydræ	219 0	7 0	N	4
75	Shimalih al Teref * *Borealior Oculorum*	λ Leonis	224 0	25 0	N	4
76	Soheil al Fard *Soheil Solitarius*	α Hydræ	227 0	5 5	S	2
77	Djenubi Ras al Asad *Australior Capitis Leonis*	ε Leonis	235 0	25 50	N	2
78	Djenubi Djebha al Asad * *Australior Frontis Leonis*	η Leonis	250 0	19 0	N	2
79	Kalb al Asad * *Cor Leonis*	α Leonis	237 0	3 0	N	1

No.	Arabic Name.	Modern Name.	Right Ascension.	Declination.	Region.	Mag
80	Menkib al Asad *Humerus Leonis*	γ Leonis	240 0	21 50	N	...
81	Aoul al Batina * *Prima Crateris*	α Crateris	250 0	15 13	S	2
82	Djenubi al Cheratan * *Australior ?*	θ Leonis	254 0	17 33	N	3
83	Al Serpha *Vicissitudo*	β Leonis	262 0	17 0	N	2
84	Minkar al Ghyrab * *Rostrum Corvi*	α Corvi	266 0	22 0	S	3
85	Djenah al Ghyrab al Eymen *Dextra ala Corvi*	γ Corvi	269 0	15 0	S	3
86	Thanih al Aoua * *Secunda Latratoris*	π Virginis	270 0	0 36	N	2
87	Laouiyet al Aoua *Angulus Latratoris*	γ Virginis	276 0	1 13	N	3
88	Rijil al Aoua * *Pes Latratoris*	μ Virginis	277 0	21 0	S	3
89	Al Simak al Azal * *Al Simak Inermis*	α Virginis	287 0	8 0	...	2
90	Ramih al Ramih *Lancea Lanceatoris*	η Boötis	294 0	21 0	N	4
91	Wasat al Ghafr * *Media ?*	κ Virginis	298 0	8 0	S	4
92	Al Simak al Ramih *Al Simak Lanceator*	α Boötis	300 0	22 0	N	1
93	Menkib al Aoua al Aisr * *Humerus Sinister Latratoris*	γ Boötis	304 55	13 25	N	2
94	Mintek al Aoua *Cingulum Latratoris*	ε Boötis	307 5	...	N	2
95	Anwar al Ferkadain* *Fulgens Vitularum*	β Ursæ Minoris	307 0	76 20	N	2
96	Nir al Fekah * *Lucida ?*	α Coronæ	321 20	30 0	N	3
97	Al Niyat al Aoul * *Prima rov al Niyat*	σ Scorpii	330 0	24 0	S	2
98	Kalb al Akrab * *Cor Scorpionis*	α Scorpii	332 0	27 38	S	1
99	Al Niyat al Thanih * *Secunda τοῦ al Niyat*	τ Scorpii	333 0	25 0	S	3
100	Al Sabyk al Aoul * ?	ζ Ophiuchi	334 0	...	S	...
101	Al Sabyk al Thanih * ?	η Ophiuchi	342 0	...	N	3
102	Menkib al Hadi * *Humerus ?*	...	343 0	11 0	N	3

No.	Arabic Name.	Modern Name.	Right Ascension.	Declination.	Region.	Mag.
103	Ras al Djathi * *Caput Ingeniculi*	α Herculis	344 56	44 0	N	2
104	Menkib al Djathi al Aisr * *Humerus Sinister Ingeniculi*	δ Herculis	345 0	14 0	N	...
105	Aoul al Shaoulat * *Prima Caudæ (Scorpionis)*	υ Scorpii	346 5	36 50	S	3
106	Thanih al Shaoulat * *Secunda Caudæ (Scorpionis)*	λ Scorpii	349 0	30 0	S	...
107	Fekhyz al Djathih al Aisr * *Femur Sinistrum Ingeniculi*	ι Herculis	350 0	13 20	N	3
108	Mirfek al Djathih al Aisr *Cubitum Sinistrum Ingeniculi*	μ Herculis	351 0	28 0	...	2
109	Rekbet al Djathih al Aisr * *Genu Sinistrum Ingeniculi*	θ Herculis	355 0	31 0	...	2
110	Aoul al Waridah *Prima τοῦ al Waridah*	γ Sagittarii	357 0	30 0	S	2
111	Thanih al Waridah *Secunda τοῦ al Waridah*	δ Sagittarii	358 0	30 0	...	4
112	Thalath al Waridah * *Tertia τοῦ al Waridah*	ϵ Sagittarii	359 0	30 0	S	3

Errors in R.A. of Al Achsasi and Al Tizini (reduced) for 1650.

	Al Achsasi.	Al Tizini.		Al Achsasi.	Al Tizini.
	° ′	° ′		° ′	° ′
α Arietis	−0 53	+0 30	α Virginis	+0 18	+0 12
α Ceti	+0 26	+0 17	α Boötis	+0 5	+0 13
γ Tauri	+0 2	+0 37	α Scorpii	+0 0	+0 27
α Aurigæ	−0 44	+0 44	α Herculis	+0 16	+0 14
β Orionis	−0 26	+0 28	α Lyræ	+0 37	+0 3
β Tauri	−0 13	+0 38	γ Aquilæ	+0 8	−0 7
α Geminorum	−0 19	+0 34	α Aquilæ	+0 21	−0 7
α Canis Minoris	−0 13	+0 6	α Capricorni	+0 55	+0 24
β Geminorum	−0 56	−0 33	α Piscis Australis	+0 28	+0 38
α Hydræ	−0 35	+0 3	α Pegasi	+0 46	+0 30
α Leonis	−0 24	−0 4	δ Pegasi	+0 24	+0 40
β Leonis	−0 47	−0 10	γ Pegasi	+0 31	+0 37

Notes.

1. Al Waridah = γ, δ, ϵ, and η Sagittarii, forming a trapezium, and signifies (the ostrich) going to drink at the river, *i.e.*, the Milky Way.

3. Al Sadirah = σ, ϕ, τ, and ζ Sagittarii, forming another trapezium, and signifies (the ostrich) returning from drinking.

4. Written Al Nesl for Al Nesr.

6. Not in Al Tizini.

8. The name Al Beldat, meaning "The Town," is given to a space in Sagittarius void of conspicuous stars. The Lucida of Al Beldat is therefore the brightest star nearest to this space.

13. The Declination is wrong.

14. Aquila is named in this MS. Al Nesr, the Vulture; Al Ghyrab, the Crow; and Al Akab, the Eagle.

16. Al Dzabihh, the Sacrificer = α and β Capricorni.

17. The Declination should be 39°. The scribe has been very careless in writing the Keff ك = 20. In some cases he has first written a Lam ل = 30, which he has subsequently altered by a diagonal stroke to a ك, and sometimes omitted doing so, which explains the errors in the Declinations of 71 and 84.

19. Cf. Al Sufi (Schjellerup), p. 189, as to the explanation of the name Saad Bula = Fl. 7, μ and ϵ Aquarii.

20. Saad al Saaoud = β and ξ Aquarii according to Ulugh Beg, but Al Sufi and Ideler give in addition ϵ Capricorni. The Declination is wrong.

23. Al Achbiya = γ, ζ, π, and η Aquarii.

26. Called by Al Tizini Nir Saad al Naam. Al Sufi gives Saad al Naam as τ and υ Pegasi, with neither of which does Al Tizini's position accord. Al Achsasi calls it Saad al Bahaim, which name is given by Al Sufi to θ and ν Pegasi. The position in both Al Tizini and Al Achsasi is that of ζ Pegasi.

28 and 29. Al Mukdim signifies "anterior," and in the description of these stars the words Al Ferg should precede. Al Ferg signifies the place between the handles of a bucket over which the water is poured.

31. This star is written in the MS. "Keff al Salsalat." In Al Tizini and Al Sufi it is called "Al Musalsalat." The Declination is quite wrong for ι Andromedæ.

33 and 34. Al Muchir signifies "posterior," and in the description of these stars the words "Al Ferg" should precede.

35 and 39. Scribe has written Declination 13 ١٣ for 18 ١٨.

36. Written الشرشا, probably in error for الرشا.

37. Al Naamet, the Ostriches = τ, υ, ζ, θ, and η Ceti.

40. The star Al Djedi is out of its place, R.A. should be 95° 17′.

43. Al Sheratein, the Marks = β and γ Arietis.

44. Schjellerup translates Al Natih as "celui qui frappe de la corne."

46. Al Botein = δ, ϵ, and ρ Arietis. Dorn gives Nir Al Botein as δ Arietis, but the positions in Al Tizini and Al Achsasi do not agree with any of the above stars.

47. Declination 7° 11 for 2° 11.

51. It is commonly understood that the name Al Debaran belongs solely to the star α Tauri, and in Al Sufi it is restricted to that star; but it is certain that by many Oriental astronomers it was applied equally to the five stars α, θ, γ, δ, and ϵ Tauri, which form the Hyades. In this MS., No. 51, γ Tauri is called "The first star of Al Debaran," and No. 52, α Tauri, is "The bright star of Al Debaran." In the Alfonsine Tables, printed in 1483, γ Tauri, which is the eleventh star of Ptolemy's *Catalogue of Taurus*, is described thus: "Que sūt (sic) supra narē earū q̄ sūt ī facie et sūt stelle Aldebram"; and the name Al Debaran is not given at all to the fourteenth

star = α Tauri. The same words occur in a more correct form in the *Liechtenstein Almagest* (1515): "Que est super narem earum que sunt in facie: et sunt stelle Aldebarã," showing that Gerard of Cremona, whose translation this is, employed in the twelfth century a similar Arabic text to that used by Alfonsus in 1252.* But the description of α Tauri contains these words (writing the Latin *in extenso*): "Lucida, quæ . . . est ex forma Aldebaran quinta." Liechtenstein states definitely that the bright star α Tauri "is the fifth star of the figure Aldebaran." In Hyde's translation of Ulugh Beg the name Al Debaran is written against the above five stars, a point which Baily omitted in his edition.

Clearly, therefore, the name Al Debaran was used at Cairo and Samarkand, and also by Occidental Arabs, to designate not one star, but the five principal stars of the Hyades.

52. Declination is wrong.

55. Al Aiouk. No satisfactory explanation of the meaning of this name has hitherto been found.

56. The Declination is wrong.

61. Certain stars are designated "Al Yemeniat" clearly from the adjectival meaning of the word "the right" or "the right hand." But in the case of 64 α Canis Majoris, Al Sufi explains that the word signifies that the star *sets* in the direction of Yemen. Similarly in the case of 70 α Canis Minoris, he states that this star is called "Al Shamiyat," because it *sets* in the direction of Syria. It would seem that there is a mistake here, and that for "sets" we should read "rises."

62. Al Sufi says that a star which precedes a brilliant star is termed Al Mirzem. Scribe has written R.A. 173° for 183°.

63. Al Henat signifies "a mark burnt on the right side of a camel's neck." It is not quite certain which stars formed Al Henat, but according to Al Sufi they were either γ and ξ, or ν and γ Geminorum.

62 to 64. The scribe has written ع for ف in the Right Ascensions.

65. Al Adzari, "the Virgins" = o^2, δ, ε, and η Canis Majoris.

67. The Declination is that of η Canis Majoris. This star is not in Al Tizini.

69. Al Dzira, "the arm," "the foreleg" = α and β Geminorum.

72. This name is not in Al Tizini.

73 Al Nethra signifies the place under the nose between the moustachios, *i.e.*, of the Lion, the Arabian constellation of the Lion being in Cancer.

74. The first word is undecipherable.

75. Al Teref or Al Tarf = λ Leonis and κ Cancri. The R.A. is 4° in error.

78. The R.A. is clearly written 250°, but should be 237°.

79. Declination 3° for 13°.

81. The MS. has الباطنه instead of الباطيه. The Declination gives 35° for 15°; a common mistake in Arabic MSS. This star is not in Al Tizini.

82. The MS has الخراسان for الخرتان.

* This is most probable, seeing that there is evidence from two MSS. at Merton College, Oxford, that Gerard of Cremona made some of his translations, from Arabic into Latin, at Toledo, where the Alfonsine Tables were constructed in the following century.

86. Al Aoua, the howling dog = β, η, γ, δ, and ε Virginis.

88. Not in Al Tizini. The scribe has written R.A. 277° probably for 287°

89. Al Simak. The meaning of this word is obscure. *Cf.* Ideler and Schjellerup.

91. In the Declination the scribe has written ع for ح.

93. Error in Declination of 13° يج for 38° لج

95. R.A. and Declination both wrong. The correct Declination is written against 94. Al Ferkadain, the Calves = β and γ Ursæ Minoris.

96. The meaning of the name Al Fecca is quite obscure. Declination is erroneous.

97. Al Niyat means "the vein which suspends the heart," and applies to σ and τ Scorpii, situated on each side of the heart of the Scorpion.

98 and 99. The Declinations should be interchanged.

100 and 101. Al Sabyk. Lane gives the meaning as "preceding," and says it is applied to stars which precede others. The Declinations of both stars are wrong for ζ and η Ophiuchi.

102. The name is clearly written, الحادي, Al Hadi, which is probably a mistake for الجاثي. The R.A. and Declination do not accord with any star in Hercules or Ophiuchus.

101 to 104. The Declinations of these stars are all wrong, and they suggest that the scribe has taken from Al Tizini by mistake the Declinations of 276, 277, 278, and 280, instead of 280, 281, 282 and 283. A comparison of the two catalogues here offers from these errors the strongest evidence of the source whence all the positions were obtained. The Declinations of 101 to 112 are mostly erroneous.

104. In the description الحاوي is written for الجاثي.

105. Al Shaoulat, "the upraised tail of the Scorpion" = υ and λ Scorpii.

107 to 109. In the description الجاني is written for الجاثي.

Note on the Proper Motion of Arcturus. By W. T. Lynn, B.A.

The large southerly proper motion of *Arcturus* was noticed by Halley so long ago as 1718, and twenty years afterwards Cassini II. estimated that its latitude had changed by about five minutes between the time of Tycho Brahé and his own, a century and a half later. Hornsby has an elaborate paper (read 1772 December 24) on it in vol. lxiii. of the *Philosophical Transactions* (p. 93), in which he determined the star's southerly proper motion to amount to 2′ 36″·81 in seventy-eight years, or about 2″·01 annually. This value is remarkably near the truth.

As it seems to me that the value now usually adopted is slightly too small, I have made a new determination from com-

paratively recent Greenwich observations, which forms the subject of this note. In the first place I have compared the R.A. and N.P.D. in Pond's Catalogue of 1112 stars for 1830 with the Ten-year Catalogue for 1880, and secondly I have compared together the places given in the Nine-year and Ten-year Catalogues respectively. The two results are very close, as might be expected from the large number of observations included in the catalogues; and they, therefore, probably represent the true amount of motion with great accuracy.

Pond's place for 1830 is R.A. $14^h\ 7^m\ 54^s{\cdot}63$, N.P.D. $69°\ 55'\ 42''{\cdot}70$. The precession in R.A. is $+2^s{\cdot}8132$, and the mean precession in N.P.D. for the interval between 1830 and 1880, allowing for the secular variation, is $+16''{\cdot}962$. Applying these for fifty years, we find the place reduced to 1880 is R.A. $14^h\ 10^m\ 15^s{\cdot}29$, N.P.D. $70°\ 9'\ 50''{\cdot}80$. The actual place for that year in the Ten-year Catalogue is R.A. $14^h\ 10^m\ 11^s{\cdot}286$, N.P.D. $70°\ 11'\ 32''{\cdot}09$. The differences are $-4^s{\cdot}004$ in R.A. for fifty years, or $-0^s{\cdot}080$ annually; and $+1'\ 41''{\cdot}29$ in N.P.D. for fifty years, or $+2''{\cdot}02$ annually.

The place in the Nine-year Catalogue for 1872 is R.A. $14^h\ 9^m\ 49^s{\cdot}390$, and N.P.D. $70°\ 9'\ 0''{\cdot}09$. The mean precession is in R.A. $+2^s{\cdot}8132$ and in N.P.D. $+16''{\cdot}9135$, making for eight years $+22^s{\cdot}505$ and $+2'\ 15''{\cdot}31$ respectively. Applying these, the place reduced to 1880 is R.A. $14^h\ 10^m\ 11^s{\cdot}895$ and N.P.D. $70°\ 11'\ 15''{\cdot}40$. Comparing these with the place in the Ten-year Catalogue, given above, we find the annual proper motion of the star to be $-0^s{\cdot}0761$ in R.A. and $+2''{\cdot}086$ in N.P.D. It is evident that the actual proper motion in N.P.D. exceeds two seconds, though that used in the last Greenwich Catalogue is $+1''{\cdot}977$ (slighly larger than the B.A.C. value), which seems to be about $0''{\cdot}1$ too small. The proper motion in R.A. seems to be a little less than $-0^s{\cdot}08$, which the value assigned in the Ten-year Catalogue ($-0^s{\cdot}0799$) approaches very closely indeed.

For a further check, I have compared the place in the Greenwich New Seven-Year (epoch 1864) with that in the Ten Year. In forming these, as well as that in the Nine-year Catalogue, the fractional parts of the proper motion were applied to the result of each observation. Whether Pond did so or not seems doubtful. The so-called annual precession for *Arcturus* in his catalogue is in N.P.D. what we should call annual variation, and includes the proper motion as determined by Baily; but whether the fractional parts were used in reducing the separate observations does not appear.

The place in the Greenwich New Seven-year Catalogue is R.A. $14^h\ 9^m\ 27^s{\cdot}52$, N.P.D. $70°\ 6'\ 29''{\cdot}32$; that in the Ten Year is R.A. $14^h\ 10^m\ 11^s{\cdot}286$, N.P.D. $70°\ 11'\ 32''{\cdot}09$. The mean annual precession is in the former element $+2^s{\cdot}8131$, and in the latter $+16''{\cdot}923$; for sixteen years, $+45^s{\cdot}010$ and $+4'\ 30''{\cdot}77$. Comparing, then, the First Seven Year place reduced to 1880 (R.A. $14^h\ 10^m\ 12^s{\cdot}53$, N.P.D. $70°\ 11'\ 0''{\cdot}09$)

with that in the Ten Year, we find the annual proper motion in R.A. to be $-0^s\cdot078$ and in N.P.D $+2''\cdot0000$. This value is probably very accurate. The number of N.P.D. observations in the New Seven-Year is 103, and in the Ten-Year 184.

Blackheath: 1895 *May* 22.

Note on the Binary ι Leonis. *R.A.* $11^h\ 18^m\ 27^s$, *Dec.* $11°\ 6'\cdot5$, 1895. ($3^m\cdot9$ *and* $7^m\cdot1$.) By Alice Everett, M.A.

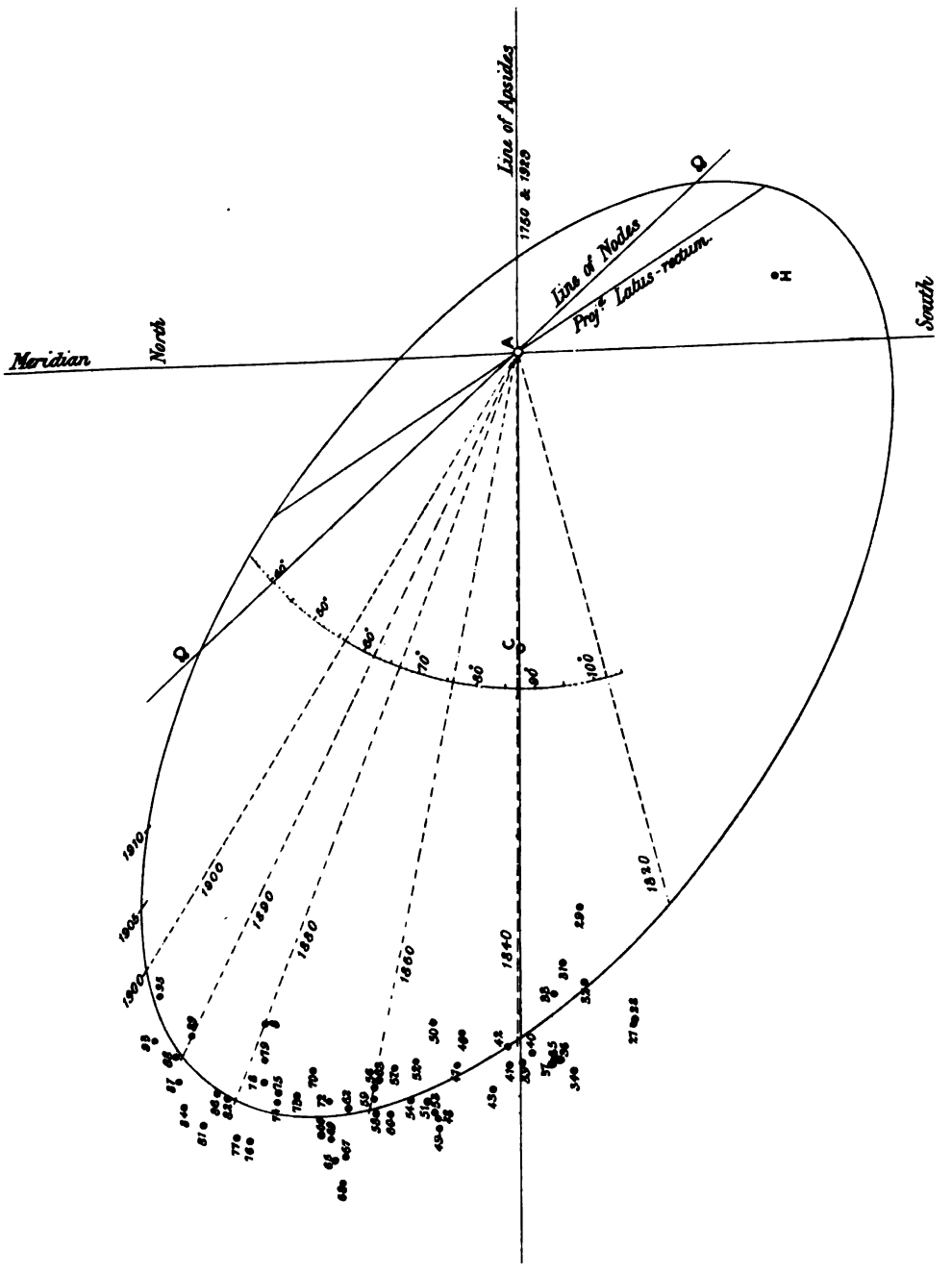
(*Communicated by T. Lewis.*)

Mr. Lewis, who had a suspicion that the companion star had passed the apse of its apparent orbit since Struve's time, suggested this binary among others to me for discussion. I have examined the measures, and, unless appearances are very misleading, think there is little doubt that the apse was passed recently, probably in the neighbourhood of 1880, and also, that maximum apparent distance was passed towards the end of the 'seventies, and that the distance is now diminishing comparatively rapidly. Another ten or fifteen years should settle the question, and as there seems to have been a tendency of late years to let the star drop out of observation, it is perhaps worth while to mention that there is at least a possibility that it is now at a rather critical part of its period. Measures were frequent from the time of Struve's first observation in 1827 until about 1883. I have not found any for the years 1885, 1890, 1891, 1892, and of those in the intervening years no two are by the same observer. This year's observation was made with the Greenwich 28-inch. The latest measures give—

1893·35	$\theta = 59°\cdot5$	$r = 2''\cdot625$
1895·29	$\theta = 58\cdot2$	$r = 2\cdot492$

The position angle has diminished about 40° since 1827. The period can scarcely be less than a century and a quarter; I am inclined to think it is nearer two centuries, and it may be a good deal more. At the present stage the computation of a satisfactory orbit is out of the question, but I have made an attempt at a provisional orbit with the view chiefly of getting a trial ephemeris for the next few years. The results are—

$P = 178\cdot6$ years	$\Omega = 40°\ 15'$
$T = 1750\cdot6$	$\lambda = 249°\ 0'$
$e = 0\cdot7566$	$a = 2''\cdot486$
$\gamma = 65°\ 40'$	$\mu = -2°\cdot016$



Cattlewood & Co.ᵗᵈ Lith. London.

The following are comparisons between observed and computed positions made at about five-yearly intervals. The mean of the observations in any year is taken :—

	θ			r		
	O.	C.	C−O.	O.	C.	C−O.
	°	°	°	″	″	″
1827·28	97·1	96·2	−0·9	2·30	2·09	−0·21
1829·37	93·9	94·5	+0·6	1·89	2·13	+ ·24
1835·33	90·4	90·4	0·0	2·40	2·24	− ·16
1836·40	90·6	89·7	−0·9	2·43	2·27	− ·16
1841·31	86·8	86·5	+0·3	2·40	2·35	− ·05
1846·31	82·8	83·5	+0·7	2·31	2·43	+ ·12
1851·42	80·4	80·7	+0·3	2·54	2·50	− ·04
1856·32	76·3	78·0	+1·7	2·53	2·56	+ ·03
1860·33	77·8	76·0	−1·8	2·60	2·61	+ ·01
1865·43	74·4	73·4	−1·0	2·79	2·65	− ·14
1866·30	73·5	73·0	−0·5	2·73	2·66	− ·07
1870·29	71·4	71·1	−0·3	2·52	2·68	+ ·16
1875·28	69·4	68·7	−0·7	2·63	2·70	+ ·07
1876·33	68·5	68·5	0·0	2·82	2·70	− ·12
1879·36	67·8	66·8	−1·0	2·54	2·70	+ ·16
1881·35	65·1	65·8	+0·7	2·82	2·69	− ·13
1884·53	63·3	64·3	+1·0	2·78	2·68	− ·10
1886·37	65·1	63·5	−1·6	2·69	2·66	− ·03
1889·16	61·9	62·1	+0·2	2·56	2·63	+ ·07
1893·35	59·5	60·0	+0·5	2·62	2·58	− ·04
1895·29	58·2	58·9	+0·7	2·49	2·53	+ ·04
			Ephemeris.			
1900·0	...	56·3	...	...	2·43	
1905·0	...	53·3	...	...	2·28	
1910·0	...	49·8	...	...	2·07	

Greenwich : 1895 *June* 14.

On the Variable Nebulæ of Hind (N.G.C. 1555) and Struve (N.G.C. 1554) in Taurus, and on the Nebulous Condition of the Variable Star T Tauri.

By E. E. Barnard, M.A., D.Sc.

The subject of the variability of the light of a nebula is of the highest importance. There are many of these objects that have been reported variable; but so differently do many of the nebulæ appear in different telescopes and with different magnifying powers, that no sort of confidence can be placed in most of these statements, and a positive proof of an actual variable nebula, except in one case, is sadly wanting. It is quite reasonable to believe that some of the nebulæ do vary in their light, but, from the peculiarities above mentioned, it will take decidedly strong proof to convince astronomers who are familiar with these objects that some deception has not misled the observer.

A better example of this kind of error is scarcely wanting than the celebrated *Merope* nebula of the *Pleiades*, which for so many years was believed by half the astronomers to be variable, while the other half refused to believe that it existed at all, but I think, since it has been so easily and repeatedly photographed, that few will call it variable now, and no one will doubt its existence.

This, however, is a class of nebula that needs, from its diffused nature, a low power and large field, for contrast, more than anything else, to make it visible. It is therefore particularly suited for small telescopes.

The more definite and condensed nebulæ are not so much subject to deceptions of this kind, due to telescope and magnifying power, and estimates of their brightness by different observers with different instruments in many cases do not vary greatly, so that any very great discrepancy in descriptions by careful observers might be suggestive of actual variability. Such nebulæ are better seen in the more powerful telescopes.

To this latter class we must refer Hind's variable nebula in *Taurus*. This object was discovered by Mr. J. R. Hind, 1852 October 11, at Mr. Bishop's Observatory, London.

It remained visible for a few years, with ordinary telescopes, and then seems to have faded from view.

In *Astronomische Nachrichten*, No. 839, we find Mr. Hind's original account of the discovery of this object. He says: "Last night (October 11) I noticed a very small nebulous-looking object in A.R. $4^h\ 11^m\ 50^s$ $\delta = +19°\ 8'$ for 1825·0, the epoch of our ecliptic charts; it was south, preceding a star of 10 mag., which, to my surprise, has escaped insertion on the map for 4^h R.A. recently published—possibly it may be variable. [This is the variable star T *Tauri*.] The sky at the time was remarkably clear, but the object appeared faint; it preceded $1^s{\cdot}2$, and was $0''{\cdot}7$ south of it [of T *Tauri*]. I suppose it will

prove a new nebula, none of our catalogues having anything in the above position. Its diameter did not exceed 30″."

This was written 1852 October 12. This nebula was subsequently observed by D'Arrest, Struve, Lassell, and others. D'Arrest measured its position on four occasions during 1855 and 1856, but on 1861 October 3 it had disappeared. On that date he makes the following note: "I am not able to find any trace of this nebula, first seen by Hind in 1852. It was observed the first time by me, and frequently, during the years 1855 and 1856. Its position being determined four times. . . . Is not this nebula variable?"

He sought for it again 1861 October 4: "Sky very clear. I have examined the region with extreme care, aided by Schjellerup; the nebula is certainly absent."

Again he says: "I have searched for this nebula, with curiosity, under varied conditions during the months of 1862 January and February, but have found no certain evidences of it. That it has vanished meanwhile from the sky is attested by many astronomers, with more powerful telescopes than mine."

He states, however, that O. Struve and Lassell, with their great telescopes, never entirely lost this object during 1861 to 1864, but that by 1868 it had also absolutely vanished from the Pulkowa telescope.

When examining the region of this object early in 1868 Struve found another small nebula 4′ preceding the place of Hind's nebula. This was subsequently observed by D'Arrest, who was sure that no nebula previously existed at that place.

Both these nebulæ were observed by D'Arrest on three or four occasions, but, of course, not on the same dates. From these positions he gives the places of these objects for 1868·0:

	h m s	° ′ ″
Struve's Nebula	α 4 14 0·4	δ +19 12 13
Hind's Nebula	4 14 15·5	+19 12 27

He says (*A. N.* 1689), "Struve's nebula is pretty small, nearly round, with eccentric nucleus = × 14 mag. In a full dark sky it would be equal to Herschel's Class II. Hind's variable nebula in 1856 was larger and considerably brighter [than Struve's in 1868]."

He would place Hind's object as faint in Herschel's Class I.

In the above paper D'Arrest gives the place of T *Tauri* 1868·0.

$4^h\ 14^m\ 17^s{\cdot}8 \qquad +19^\circ\ 13'\ 4''.$

In observing Hind's nebula, 1855 November 3, D'Arrest thus describes it: "Discovered by Hind, *Astr. Nachr.* No. 839. A very bright nebula, 1′ in diameter; on its northern edge is a 10^m star, which follows $2^s{\cdot}20$, and is about 35″ north of the middle of the nebula."

In *A. N.* 2212 Tempel has a very important and interesting

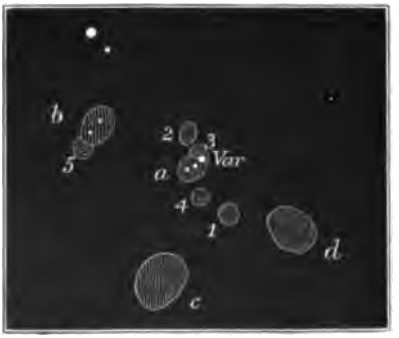
account of his observations of this region. They were made in 1877, and all the dates below refer to that year.

On November 5 he could see no nebulosity near T *Tauri* in the place assigned to Hind's nebula. On November 8 he found a nebula $1\frac{1}{2}'$ diameter, in the northern part of which a small star shone. This nebula was 1′ south and 15ˢ preceding T *Tauri*, and was recognised by him as the Struve nebula.

On December 12 he saw, in a very clear sky, two very small stars very close to T *Tauri*, but could see no nebulous appearance as he had so often seen previously. He could not see anything of the Struve nebula which he had seen November 8, but he saw two small stars at its place, the northern of which was the one he had seen on November 8 in the nebula, and which was about 40″ south following.

Tempel gives a very interesting sketch of the region in the paper referred to. This I have thought of sufficient interest to be here reproduced, so I send a copy of it. This is valuable, as it seems to point to the existence of several variable stars in this remarkable region.

Tempel found that the different positions of Hind's nebula as previously reported did not very well agree, so he has charted each of these for comparison.



1 = Hind's position as given by him in *A.N.* 839.

2 = The same, from Hind's description.

3 = Auwer's position. Herschel's Gen. Catalogue.

4 = D'Arrest's position in *Std. Nebulosorum.*

5 = Struve-D'Arrest's position in Dreyer's supplement to Gen. Cat. = the place of Struve's nebula.

a = The nebulous appearance which Tempel had so often seen about T *Tauri*, and where later he saw only two small stars without any nebulosity.

b = The nebula which he (Tempel) had seen 1877 November 8, and which he recognised as Struve's nebula. The southerly of the two small stars at this point is the one described by D'Arrest as being excentrically placed in the Struve nebula.

c and *d* are small star clusters seen by Tempel. The scale of this sketch is 1 millimeter = 1ˢ.

Dr. Dreyer, in his Supplement to Herschel's Gen. Cat. of Nebulæ, says in 1877 : "No. 1689 of the *Astr. Nachr.* contains an observation by D'Arrest of an S nebula with an excentric nucleus

= ✲ 14^m, which was first seen by O. Struve early in 1868, 15^s p. the place of the missing [Hind's] nebula. At present there is no nebulosity distinctly visible, neither around this faint star, nor near the well-known variable star. On this point I am in perfect accordance with Dr. Copeland, observing with the large Dunecht refractor, and M. Tempel, who works with a fine Amici refractor of eleven-inch aperture (at Arcetri). In the Pulkova refractor, however, some traces of nebulosity seem still to be visible. M. Otto Struve informs me that he, from time to time, has observed the variable nebula, but that he avoids reducing and comparing his observations for fear of being pre-occupied with respect to this minimum visible. He does not consider the *Nova* from 1868 a separate nebula. 'What I see is certainly the variable nebula itself, only in altered brightness and spread over a larger space. Some traces of nebulosity are still to be seen exactly on the spot where Hind and D'Arrest placed the variable nebula.' "

After this these objects seem to have been fairly neglected by observers until 1890, when Mr. Burnham took up the matter with our great refractor. His paper on the subject was printed in *Monthly Notices* for 1890 December. As he states, he examined this region only under the best atmospheric conditions.

Misled by the position of T *Tauri*=*D.M.* + 19°·706 given in *D.M.*, he erroneously assumed that Hind's nebula was identical with the variable star. He says: "The place of the nebula as given by Dreyer, on the authority of D'Arrest, is identical with that of *D.M.* + 19°·706, the magnitude of which was estimated by Argelander as 9·4; and this is T *Tauri* of the variable star catalogues." This statement is true, but the position of *D.M.* + 19°·706 as given in *D.M.* is erroneous.

The *D.M.* place of this star and the position of Hind's nebula, reduced to 1855·0, are as follows:

D.M. + 19° 706	α = 4 h 13 m 31·2 s	+ 19° 10′·6
Hind's Nebula	= 4 13 31	+ 19 10·5

A sufficiently close agreement to suggest identity, which was further heightened by the fact that Mr. Burnham found that T *Tauri was* a nebula!

But, singularly enough, the *D.M.* place of T *Tauri* is about 1^s·8 too small in *A.R.*, and 0″·7 too small in δ, almost exactly the difference in right ascension and declination between the true place of Hind's nebula and T *Tauri*. So much so, indeed, that the *D.M.* place of T *Tauri* actually agrees with the position of Hind's nebula as given by D'Arrest!

Chandler, in his Variable Star Catalogue, *A.J.* 179, gives the place of T *Tauri* for 1855·0

$$4^h\ 13^m\ 33^s \qquad +19^\circ\ 11''\cdot3$$

and this is the true place.

On the assumption, therefore, that T *Tauri* was Hind's nebula, Mr. Burnham says, in his paper: "This small star, if it is a star, is placed within a very small condensed nebula. It is somewhat elongated in the direction 151°·7. A rough reading of the wires gave 4″·4 for the length of the nebula in this direction. It is less extended on the opposite side of the star or nucleus, with a shorter diameter of perhaps half that measured. It was examined with various powers, but it was impossible to say whether or not it had a disc like that of an ordinary star. If it were the bright nucleus of the small nebula, it would probably present the same stellar appearance. It will be noticed that the description of the nebula does not correspond with that of the early observations, where it was noted, when it was seen at all, as about 1′ in diameter."

Mr. Burnham asked me to examine this object with him, and I well remember that the small star was placed in an elongated nebula just as he describes.

The nebula was conspicuous and definite, not a nebulous glow. One would not hesitate a moment as to its being a very small fairly bright definite elongated nebula, the star to all appearance simply being a nucleus to the nebula.

In examining this region with the 36-inch at Mr. Burnham's request with him, I saw a very faint nebula close south preceding T *Tauri*. Of this Mr. Burnham says: "On [1890] October 15 I asked Mr. Barnard to examine this region with the large telescope. . . . After careful attention he was able to see an excessively faint round nebula, about $\frac{3}{4}'$ from the one previously described [T *Tauri*], in the estimated direction of 185°. This faint nebulosity was about 40″ or 50″ in diameter, and apparently not connected with the variable, and was of nearly the last degree of faintness for the light-power of the large instrument. It is perhaps too faint for any other telescope. Neither Mr. Barnard nor myself on any occasion could see the slightest trace of the OΣ nebula (seen also at times by D'Arrest, Tempel, and others, but invisible in the Rosse reflector), which should be 15^s preceding Hind's, nor any nebula in the immediate vicinity. Subsequently we looked at the small nebula [T *Tauri*] with the 12-inch telescope, by way of getting a better estimate of its magnitude, and found that it was a very faint object, and in appearance precisely like any ordinary star of that magnitude. The nebulous surrounding was completely lost with the smaller instrument. I do not think it can be any brighter now than 12·5 magnitude of the scale used in my double star observations."

As a proof of the nebulous character of T *Tauri*, I quote from Mr. Burnham's paper further: "On the night of November 1 Mr. Keeler examined the nebula [T *Tauri*] with the small spectroscope, and found that it was probably of the usual gaseous type, although on account of the extreme faintness of the nebula only the principal line at λ 5005 was visible. The spectrum of the nucleus could not be seen."

It will be noticed here that though Mr. Burnham was erroneously led, by the error in the *D.M.*, to identify Hind's nebula with T *Tauri*, he discovered the important fact, which was previously unknown, that the variable star T *Tauri* is a nebula—or a nebulous star.

I have quoted thus extensively from Mr. Burnham's paper, because I have recently made some observations of these objects that bear directly upon his work, as will be seen.

During his examination of this region Mr. Burnham—whose excellent custom it is to measure everything he comes across that is measurable, and who does not leave on record a simple statement only of what he has seen—measured the position of T *Tauri* with reference to the brighter star *D.M.* + 19°·704 (which is *W.B.* 4^{h}·274). He first measured the difference of declination, and got

1890·775	Δδ	243″·65
·777		243·40

He then measured the position angle and distance,

			Mags.	
1890·775	43°·5	336″·31	8·3	11·7
·777	43·8	336·07	8·4	12·5

From these last I derive the following differences (T *Tauri*—*W.B.* 4^{h}·274):

1890·776 Δδ = + 0^{m} 16^{s}·39 Δδ = + 243″·25.

Having assumed, with Mr. Burnham, that Hind's nebula was really the nebula T *Tauri*, I paid no further attention to the subject until the past winter, when it occurred to me to look up the faint nebula I had seen close s.p. T *Tauri*.

On 1895 February 25 I examined the place with the 36-inch and found the nebula very easily; it was faint, but not extremely so. Indeed it was by first finding the nebula that I identified T *Tauri*, so different did that star look from my previous inspection of it in 1890 with Mr. Burnham.

The star was bright, not less than the 10th magnitude, and the small nebula in which it shone in 1890 had absolutely disappeared. With no power could I see the small elongated nebula of which the star had previously formed the nucleus. The additional brightness of T *Tauri* could have nothing to do with this if the nebula was as conspicuous as in 1890. The star seemed perfectly stellar and of a reddish-yellow colour.

By comparing it carefully with a star of similar colour and magnitude, 50·6 seconds preceding and 3′ north—which I shall hereafter refer to as A for convenience—I could, however, see that T *Tauri* was certainly surrounded by a very feeble indefinite nebulous glow for a few seconds of arc, but the definite nebula had certainly disappeared.

As a further identification I measured the position of the star with reference to the 8m *D.M.* star south preceding :

$$\Delta\delta + 243''{\cdot}49 \text{ (2 obs.)}$$

which agrees with Mr. Burnham's $\Delta\delta$ of 1890.

A rough difference of right ascension gave 17^s, thus showing the identification was complete, and this has been further verified (see March 28, later).

As I have said, the nebula close south preceding the variable star was easily visible. It was round, quite definite, and very feebly brighter in the middle ; and was estimated to be of about the 16th magnitude. I think it was somewhat brighter than in 1890.

The following micrometrical position was obtained (nebula—T *Tauri*) :

$$\Delta\alpha = -0'\ 26''{\cdot}05 \qquad = -0^m\ 1^s{\cdot}85 \text{ (2 obs.)}$$
$$\Delta\delta = -0\ 26{\cdot}26 \text{ (3 obs.)}$$

It did not reach to the star, from which it seemed to be entirely independent.

I also carefully examined the place of the Struve nebula. There was no nebulosity visible at this point, close to which, however, was a small star of the 14-15th magnitude. I could not fully convince myself that there was not a feeble glow about this star, but it was too uncertain to be in any way positive.

Comparing my measures of the position of T *Tauri* with that given in the *D.M.*, I found, to my surprise, that the supposed coincidence of position with Hind's nebula was due to an error in the *D.M.* position of the star. I then looked up Hind's original account of his discovery in *A.N.* 839, and saw at once from his description that his nebula was by no means identical with T *Tauri*, and that he had observed both objects at that time, and furthermore that his nebula had the exact position occupied by this faint nebula close south preceding T *Tauri*, which I had just measured ; and that, indeed, this faint nebula, seen by Mr. Burnham and myself in 1890, was nothing else but Hind's nebula of 1852, which was supposed to have vanished from the face of the heavens !

On February 26 I examined this region with the 12-inch. T *Tauri* was easily visible. I could catch the feeblest glimpses of Hind's nebula by occulting the star ; if I had not known it was there, however, I could not have seen it, it was so excessively difficult.

I estimated T *Tauri* to be of the 10th magnitude. It was of equal brightness to the star A.

On March 4, in moonlight, with the 36-inch I measured the position of the small star close to the place of the Struve nebula, with reference to the *W.B.* star ($4^h{\cdot}274$) south of it.

(Small star—*W.B.* 4^{h}·274)

$\Delta\delta = +0'\ 8''.29$	$= +0^{m}\ 0^{s}.59$ (3 obs.)
$\Delta\delta = +3\ 8.51$ (3 obs.)	

The resulting position shows this is the object mentioned by D'Arrest as being a 14-mag. nucleus excentrically placed in the Struve nebula.

On this occasion I noted: "T *Tauri* with 520 certainly surrounded with a dense hazy nebulosity several seconds in diameter. The image of the star carefully focussed, it was perfectly stellar. It was compared carefully with the star A. Both of the same colour and magnitude. A was free of the nebulous glow seen about T *Tauri*."

On March 24 I again examined the region with the 36-inch. The sky was poor. Only the vaguest traces of Hind's nebula could be seen on account of the poor sky. "Not certain, but there is a slight haziness at the place of the Struve nebula. With 350 and 520 diameters T *Tauri* seems to be a reddish star in a feeble glow of nebulosity. Compared with A, T *Tauri* is certainly feebly nebulous, but the star itself is stellar. The nebula that Mr. Burnham and I saw in 1890, in which this star was placed, certainly does not now exist. T *Tauri* is, I think, $\frac{1}{10}$ to $\frac{2}{10}$ magnitude fainter than A. I think it fainter than at previous observations. The two stars reddish and very much alike."

On March 28 with the 12-inch, from eighteen transits, I determined the $\Delta\alpha$ of T *Tauri* and the *W.B.* star 4^{h}·274—T *Tauri*

$$\Delta\alpha = +0^{m}\ 16^{s}.44,$$

which differs only 0^{s}·05 from the value derived from Mr. Burnham's measures. At this observation T *Tauri* was of the same brightness as A.

If we refer to Tempel's sketch and descriptions we shall see that these observations have shown only one star at the place of the Struve nebula where he saw two. No star was seen near T *Tauri*, close north of which Tempel saw two that had finally taken the place of a nebula which had vanished. No trace of this nebula was seen.

Tempel's work seems to have been carefully done—his stars are missing. One can hardly doubt—knowing the remarkable nature of this region—but that these objects which he saw, and which are not now visible, are variable also, or of a temporary nature.

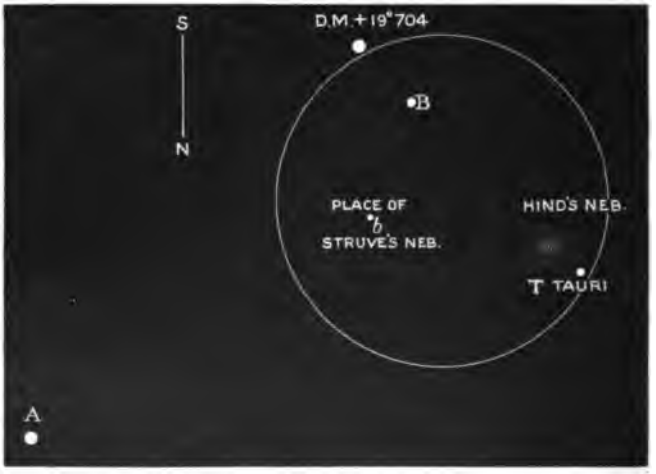
In reference to the actual nebulous condition of T *Tauri* there is no question but this star in 1890 October and November was the nucleus of a very small pretty bright nebula, as recorded by Mr. Burnham. There is also no question but that this small nebula had disappeared from the star in 1895 February and

March, and that the star was perfectly stellar, but involved in a very faint diffused nebulous glow.

At the time of Mr. Burnham's observations this variable star was at its minimum brightness, and at the present observations it was bright though not at its maximum. Is it possible that in its fainter phases this star becomes essentially a very small nebula, or the nucleus of such, and at its maximum the nebulosity is absorbed into the star, or otherwise disposed of? I hope to carefully watch this star hereafter, and try to settle some of these points.

I think it probable there is a slight fluctuation in the light of Hind's nebula, for it was, I am confident, somewhat brighter in 1895 February than in 1890 October.

I send a sketch showing the present appearance of Hind's nebula with respect to T *Tauri* and several other stars. It is less than ½′ in diameter.



The star A is the one to which the light and physical appearance of T *Tauri* were referred.

B is a 12·5 or 13 mag. star, whose place on the sketch is by eye estimation.

b is the small star which was measured by me, and which was involved in the north part of Struve's nebula according to Tempel

There may have been other faint stars in the field, but there were none near *b* nor near T *Tauri*.

From my observations of the relative positions of T *Tauri* and *W.B.* $4^{h}\cdot274$, and adopting the position of the latter star as given in the catalogue, the following is the place of T *Tauri*:

1895·0 $4^{h}\ 15^{m}\ 52^{s}\cdot39$ $+19°\ 17'\ 8''\cdot1$.

The resulting place of Hind's nebula will be

1895·0 $4^h\ 15^m\ 50^s{\cdot}54$ $+19°\ 16'\ 42''{\cdot}1$.

Also, from the *W.B.* star, the following is the position of the 14th magnitude star supposed to be the one forming the "excentric nucleus" of Struve's nebula :—

1895·0 $\alpha = 4^h\ 15^m\ 36^s{\cdot}54$ $\delta = +19°\ 16'\ 13''{\cdot}1$.

These, carefully reduced to 1860·0, become

	h m s	° ′ ″
Star in Struve's Nebula	$\alpha = 4\ 13\ 34{\cdot}39$	$\delta = +19\ 11\ 1{\cdot}6$
Hind's Nebula ...	$\alpha = 4\ 13\ 48{\cdot}37$	$\delta = +19\ 11\ 31{\cdot}1$

These objects are respectively Nos. 1554 and 1555 of Dreyer's New General Catalogue of Nebulæ ; their places, as given in N.G.C., for 1860·0 are

	h m s	° ′
Struve's Nebula (1554)	$\alpha = 4\ 13\ 33$	$+19\ 11{\cdot}0$
Hind's Nebula (1555)	$\alpha = 4\ 13\ 48$	$+19\ 11{\cdot}2$

These two nebulæ, Hind's and Struve's, make the best authenticated case of variability in the light of a nebula that we have. The facts concerning them stand incontestable.

Here were two nebulæ which less than half a century ago were easily visible in ordinary telescopes, and which were bright enough to be placed, one in Herschel's first class, the other in his second class, and which were observed and measured by the best observers then living. One of these nebulæ has disappeared from the face of the heavens, the other has become so faint that it can be seen only in the most powerful telescope.

There is a satisfaction in this—it is so above any uncertainty, and the facts are so clear, that even the feeblest doubt can never be raised to question the case.

Another Probable Variable Nebula.

There is nearly as remarkable a case as the foregoing, which I have myself encountered. Unfortunately, however, it rests alone on my own observations, and therefore has not the independent testimony of other observers that should always be required to satisfy the scientific spirit of the age. The facts are none the less true, and may some time be supported by other evidence, and so I shall insert them here to await the testimony of time.

This was the case of a nebula which I found with the 12-inch 1888 November 30. I have already called attention to this object in *A.N.* 3097, but I wish further to place it on record in this paper, as it should properly be recorded in connection with the present subject. As the account in the *Nachrichten* is clear, I shall copy a portion of it for record here, and insist that

I am still as fully convinced as I was at the time I wrote the article, that the nebula became visible as a bright object where no nebula was previously known, and then, some time between 1888 November 31 and 1891 November 22, faded down to a very faint object in the same telescope in which it had appeared conspicuously bright.

Here is the account from *A.N.* 3097 : "On 1888 November 30 I discovered a small pretty bright nebula in *Cetus*, and was surprised, from the brightness of the nebula, to find that it was not in any catalogue. I carefully measured its position with the micrometer, and examined it the next night for motion, suspecting it to be a comet. No motion being detected, it was not observed further. I have a very distinct recollection of the object, and from my description I would estimate that it was between the 9th and 10th magnitudes. In its centre was a very small stellar nucleus of the 13th magnitude. Not having seen the nebula in my subsequent sweeps in that neighbourhood, I was led in 1891 to examine its position with the 12-inch. The nebula was found with some difficulty. It was extremely faint, and was only identified by the aid of the comparison star of the previous observation. This was 1891 November 22. I estimated it to be $13\frac{1}{2}$ magnitude, $\frac{1}{2}'$ in diameter, with perhaps a faint nucleus. I again examined it on 1891 December 24, and could see a very faint nucleus. The nebula was estimated 13 magnitude, round, $\frac{1}{2}'$ in diameter. In a note it is recorded that from recollection the nebula at these last observations could not be one-fifth as bright as on 1888 November 30.

"Following are the observations of the nebula 1888 November 30 (neb − ∗) :

$$\Delta\alpha = +1^m\ 44^s{\cdot}13 \text{ (10 obs.)}, \qquad \Delta\delta = -5'\ 47''{\cdot}2 \text{ (3 obs.)}.$$

The comparison star was W_1 $0^h{\cdot}594$, the position of which for 1888·0 was $\alpha = 0^h\ 36^m\ 11^s{\cdot}58$, $\delta = -8°\ 42'\ 19''{\cdot}3$, and the position of the nebula

$$1888{\cdot}0 \quad \alpha = 0^h\ 37^m\ 55^s{\cdot}71, \qquad \delta = -8°\ 48'\ 6''{\cdot}5.$$

"The observations of 1891 November 22 gave (neb − ∗)

$$\Delta\alpha = +1^m\ 43^s{\cdot}88 \text{ (6 obs.)}, \qquad \Delta\delta = -5'\ 49''{\cdot}0 \text{ (3 obs.)}."$$

I have examined this nebula several times since with the 12-inch, but it has always been a faint object.

Mount Hamilton, California :
1895 *April* 1.

On a Great Photographic Nebula in Scorpio, near Antares.

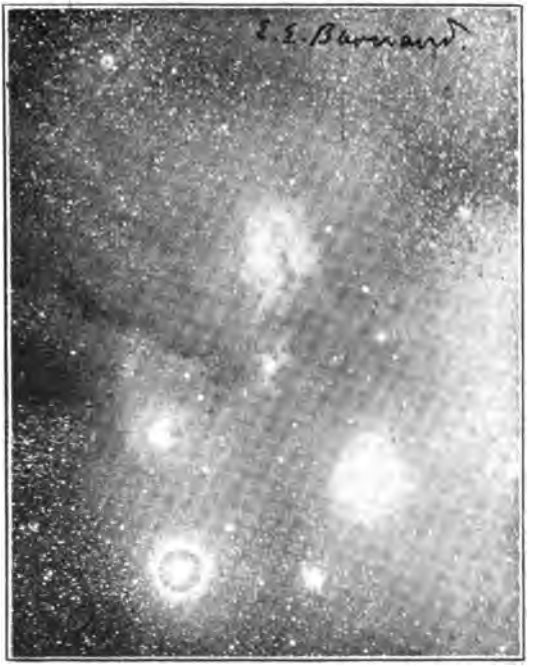
By E. E. Barnard, M.A., D.Sc.

For many years I have known of a vast but vague nebulosity in the region of *Antares*. This has been encountered in my comet seeking. It was so indefinite, however, that it could not be definitely located. With a large field, on a small telescope, the entire sky in that region seemed to be covered with a very feeble nebulosity. A portion of this I had located about 22 *Scorpii* and at other points.

I have recently photographed this region. The resulting pictures have shown that a magnificent nebula occupies a large portion of this region of the sky. The brightest portion of it condenses about the stars.

	m	h	m	s	°	′
ρ Ophiuchi, 22 *Scorpii*, and two small stars in (1875·0)	9·6	16	17	47	−24	9·3
	8·0	16	17	52	−24	10·3

This great nebula occupies a remarkably vacant region. It seems to fill in a great hole among the stars. From this vacancy



Great Nebula near *Antares*, 1895 April 19. Lick Observatory, 6 in. Willard portrait lens.

there are several vacant lanes that run easterly from it for many degrees, and which are entirely devoid of stars. Even though there were no nebula here, the wonderful appearance of the sky itself would be sufficiently remarkable to attract attention at once.

This great nebula is very intricate and complicated in form. Especially is this shown where it condenses about the above-mentioned stars. It is directly connected with σ *Scorpii* by a stream of nebulosity that widens and intensifies where it involves σ. I have made four photographs of the nebula with the Willard lens, and three with the "lantern lens." Because of its great southern declination it is not possible to give as long an exposure as I should wish.

Great Nebula near *Antares*. 1895 March 30. Exposure 2h. 8m. Lick Observatory, 1½ in. lantern lens.

I send a glass positive of one of these negatives with the Willard lens on 1895 April 19. I would call attention to the fact that the stars on this picture are very imperfect. The low altitude of the object placed the telescope in an awkward and unusual position, which caused an unexpected strain to be brought to bear on the instrument. This, however, has but little effect on the nebula, except, perhaps, to slightly mar some of the more delicate details. I have been waiting for another opportunity to give a longer and better exposure, but bad weather has prevented.

I have selected one of the negatives made with the "lantern lens," and from this I also send a glass positive. This particular picture gives one an admirable idea of the marvellous nature of this part of the sky. It also shows the nebula and its singular relation to the vacancies of that region. The Willard lens had shown feebly that all the bright stars near the nebula were involved in it.

The small picture more clearly shows this. It will be seen that a large diffused portion of it extends all over the region about *Antares* and σ *Scorpii*, and several degrees beyond.

This picture also shows a large irregular long nebula involving the star ν *Scorpii*, which was not previously known.

In looking at the larger of the two photographs, it will be seen that 22 *Scorpii* lies in a rift of the nebula, between two brightish strips which lie close north and south of it, and which are inclined to each other.

All the details shown are readily made out on all the different negatives—for both lenses.

The different pictures with the Willard lens show several other stars in this region to be nebulous. A list of these has been sent to the *Astronomische Nachrichten*.

The first of the negatives with the Willard lens (March 23), in which the stars are very perfect, shows M 4 to be a very beautiful star cluster, just sufficiently loose to show the individual stars nicely.

A word in reference to the "lantern lens." I have given an account of some interesting experiments with this lens in *Astronomy and Astro-physics* for December 1894.

This is a small magic lantern lens, from a cheap oil lantern. It is 1½ inch in diameter, and 3 inches focus from the back lens, the equivalent focus being about 5 inches. By averaging the focus it is possible, as will be seen by the picture, to get a fairly flat field over some 20° or 25°. Its action is very rapid, and the prominent cloud forms of the Milky Way are shown in some ten minutes' time. For many purposes it will be extremely valuable, far more so than any larger or more powerful lens. It is so inexpensive, and its results are so wonderful, that every amateur, and every professional observatory, should possess one. I would specially call the attention of the Society to this kind of lens, and would not wish a better specimen to illustrate its capacity than the picture I send with this (made 1895 March 30). On some of the other negatives with this lens (of this region), familiar stars are shown by having the stars in the centre in exact focus, but this hurts the rest of the field, and impairs the usefulness of the lens. It is therefore well to average the focus with a lens of this kind, and thereby extend the flatness of the field.

I am very much pleased to see that Dr. Sheldon has taken up this subject with a similar lens since I called attention to the wonderful results of such. His article on this subject will be found in the *English Mechanic*, 1895 February 15.

Mount Hamilton, California:
1895 *May* 4.

On a Photographic Study of the Earth-lit Portion of the New Moon. By E. E. Barnard, M.A., D.Sc.

I have recently been making some experiments in photographing the Earth-lit portion of the new Moon with the 6-inch Willard portrait lens. The more prominent details are easily shown in the earlier stages, before the Moon becomes too old.

I have thought it would be interesting to make a series of such photographs, both in the evening and morning phases, for the study of any peculiarities in this illumination.

The first of these pictures was made on 1895 February 26, at about half-past seven. This is a very beautiful picture. The Earth-lit globe stands out beautifully round, encircled by the slender crescent. All the "seas" are conspicuously visible, as are also the other prominent features, especially the region about *Tycho*. *Aristarchus* and *Copernicus* appear as bright specks, and the light streams from *Tycho* are very distinct.

Photograph of New Moon (enlarged). 1895 February 26. 7^h or 8^h. Exposure 30^s. Lick Observatory, 6 in. Willard portrait lens.

For the inspection of the Society I send two glass positives from this picture; the smaller one is a direct contact positive, and is consequently of the original size, while the other is enlarged a couple of times. The exposure was 30 seconds.

Mount Hamilton, California:
1895 *May* 4.

The Thermal Radiation from Sun Spots. Observations made at Daramona, Streete, co. Westmeath. By W. E. Wilson.

In 1894 March Dr. Johnstone Stoney kindly communicated to the Royal Society some observations of mine on the above subject.* In this preliminary note a full description is given of the instruments and of the method of observations. It is therefore unnecessary to again describe them, but merely to mention that a large image of the Sun is formed by means of a heliostat and projected on to a screen in the observatory. Behind this screen, and standing on a pier of concrete, is placed a Boys radio-micrometer. A small pinhole in the screen admits radiant heat into the radio-micrometer. By placing any part of the solar image over the pinhole we can measure the relative radiation of this part. Two long rods and handles come into the observatory from the heliostat, and by turning these any desired part of the solar image can be accurately placed over the pinhole aperture. The driving clock of the heliostat then keeps it in this position while an observation is being made. The standard to which all the values of radiation from spots &c. are compared is the value on an arbitrary scale of the deflection of the radio-micrometer when the centre of the solar image is allowed to fall into the pinhole aperture in the screen.

In taking an observation, the zero position of the spot of light on the scale when the pinhole is closed is first noted, and its value entered in column Z. The umbra of a spot is then placed, by means of the slow-motion handles, on the pinhole, which is then opened. The amount of deflection produced is then entered in column U. The image is then moved so that a portion near the spot, but at the same distance from the limb, falls into the pinhole. The deflection from this is entered in column N. And finally the solar image is placed centrally, and the radiation from the centre of the disc is entered in column C.

When the values in column Z are subtracted from those in U, N, and C, we get comparative values of the radiation from the umbra, the neighbourhood, and the centre of the Sun.

In a former paper † it has been shown that the deflections of the radio-micrometer are, at any rate up to 20°, strictly proportional to the amount of radiant energy falling on the instrument. We are therefore authorised in taking these values as

* *Proceedings of the Royal Society*, vol. lv.

† "Effective Temperature of the Sun," Wilson and Gray, *Phil. Trans.* vol. clxxxv. A.

equal to the amount of radiant energy reaching us from the different parts of the Sun. It has long been known that the radiation from the limb of the Sun is much less than from the centre, and that this is probably caused by a layer of what we may call smoke, which lies over the photosphere. It seemed to be an interesting point to investigate whether the radiation from a Sun spot falls off when near the limb in the same manner as a point in the photosphere, and since the commencement of these observations this point has been investigated. In the preliminary note published in the spring of 1894 I showed from observations then recorded that the radiation from the umbra of spots does *not* suffer absorption when near the limb, in the same manner as a point on the photosphere. These observations have been continued during the summer and autumn of last year and confirm the earlier ones.

In 1874 and 1875 Langley, * by means of a thermo-pile and galvanometer, measured the radiation from Sun spots. The mean value that he gives for the umbral radiation is 0·54. Instead of taking the radiation from a point in the centre of the disc as his standard, Langley took two points on the photosphere, the first situated between the spot and the centre, and the second between the spot and the limb. The mean of these two photospheric readings he then used as a divisor for the umbral reading. Langley seems to have been unable to observe that the radiation from the umbra of a spot is nearly constant for different distances from the centre of the disc. He says, "The decrement of heat as we approach the limb is, though not exactly, yet so very nearly, in the same ratio for photosphere and spots, that no correction is needed on this account." An inspection of the values of $\frac{U}{N}$ in Table I. clearly shows that the radiation from the umbra of a spot, as its distance from the centre increases, becomes closer to the value of the radiation from the neighbouring photosphere. Whereas the values of $\frac{U}{C}$ remain nearly constant. As Langley's observations were taken near a solar minimum year and mine at a solar maximum, it is just possible that the radiation from spots may vary during this period. Future observations taken throughout a complete sun-spot cycle may show that the spots are formed during the solar minimum at a lower level, and thus suffer more absorption near this limb than they do during a solar maximum.

I have collected the monthly means of my observations from August 1893 to Nov. 1894, and plotted out the values of $\frac{U}{C}$ in the following curve :—

* *Monthly Notices*, vol. xxxvii. No. 1.

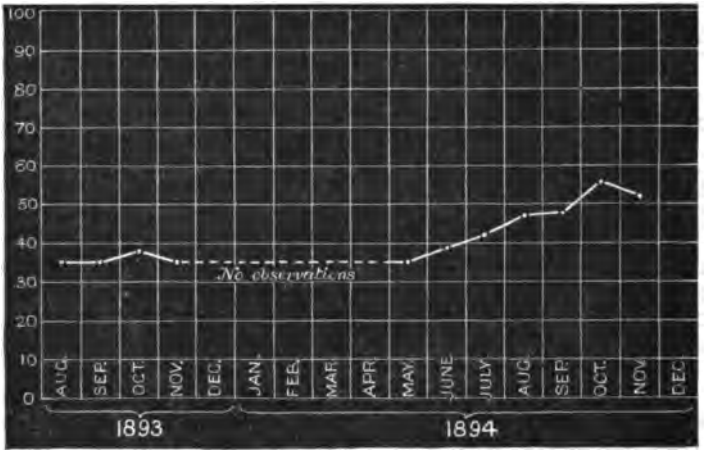


Fig. 1.—Radiation from an equal area of the photosphere at the centre of the disc = 100.

It will be seen that the umbral radiation is considerably lower during 1893, and since May 1894 the values of $\frac{U}{C}$ have increased from 0·35 to over 0·50.

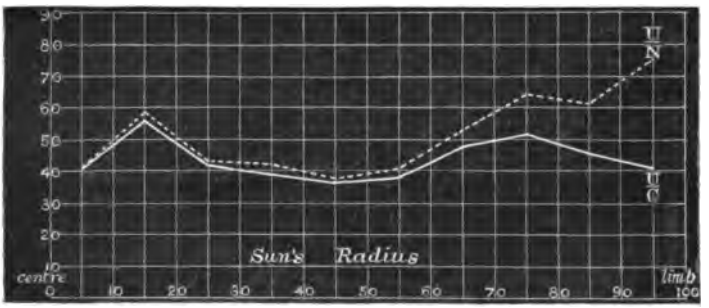


Fig. 2.—Radiation from an equal area of the photosphere at the centre of the disc = 100.

In fig. 2 I have collected the values of $\frac{U}{C}$ and $\frac{U}{N}$ according to distance along the Sun's radius. The continuous curve gives the values of $\frac{U}{C}$, while the dotted one gives those of $\frac{U}{N}$, and shows how the latter departs from the former as the limb is approached.

Since I published my first observations my attention has been drawn to a paper on this subject by Professor Frost, of

Dartmouth College, U.S.A. He there points out the same fact as I have—that the light from umbra of spots does not suffer absorption when they are near the Sun's limb in the same manner as a point in the photosphere. He also records some observations in which he found the radiation from the umbra greater than that from the neighbouring photosphere when the spot was close to the limb. I have never been able to observe this. The greatest value for $\frac{U}{N}$ that I have recorded is 0·83.

In Table I. are given the ratios of the radiation from the umbra (U), the neighbouring photosphere (N), and the centre (C). In column D is given the distance of the spot from the Sun's centre, in hundredths of the radius. Where observations are bracketed together it signifies that it is the same spot that has been observed on different days. Unfortunately, in this climate we are very seldom able to observe a spot for many days in succession.

TABLE I.

Date.		$\frac{U}{C}$.	$\frac{U}{N}$.	D.	Remarks.
1893.					
Aug.	5	0·37	0·43	60	
	7	0·29	0·29	40	
	8	0·29	0·32	50	
	8	0·34	0·38	40	
	8	0·42	0·51	90	
	14	0·36	0·37	50	
	19	0·37	0·37	50	
Sept.	2	0·31	0·31	10	
	3	0·30	0·30	10	
	4	0·42	0·45	30	
	4	0·43	0·45	30	
	7	0·29	0·35	85	
Oct.	1	0·40	0·40	30	
	1	0·49	0·57	80	
	22	0·34	0·35	52	
	26	0·36	0·41	40	
	29	0·32	0·71	90	
	30	0·36	0·78	95	
	30	0·58	0·65	...	No real nucleus.
Nov.	8	0·36	0·80	97	
	9	0·34	0·85	92	

Date.	U_C	U_N	D.	Remarks.
1894.				
May 30	0·34	0·34	...	Spot A.
30	0·32	0·34	57	Spot B
31	0 33	0·34	45	Spot A.
31	0·39	0·40	42	Spot B.
June 6	0·38	0·54	86	
30	0·41	0·61	89	Spot A.
30	0·62	0·66	...	Spot B. No definite umbra.
July 1	0·43	0·76	97	Spot A. Spot B nearly filled up.
21	0·61	0·64	60	Sky hazy.
21	0·46	0·52	58	
30	0·42	0·47	65	
30	0·38	0·78	94	
30	0·39	0·67	92	
Aug. 6	0·49	0 51	41	
22	0·46	0·70	96	
Sept. 8	0·42	0·58	74	
9	0·47	0·51	61	
10	0·43	0·45	41	
13	0·47	0·47	...	Spot nearly central.
14	0·45	0·50	53	Same spot as observed on 8th, 9th, 10th, 13th.
29	0·58	0·66	83	
30	0·55	0·61	67	
Oct. 4	0·60	0·66	72	
4	0·56	0 59	19	
4	0·55	0·64	84	
7	0·54	0 64	...	Clouds.
19	0·53	0·83	96	
Nov. 5	0·51	0·52	57	
5	0·61	0·61	5	
5	0·49	0·71	84	
8	0·42	0·83	90	
8	0·54	0·69	72	
8	0·58	0·60	40	
30	0·48	0·80	94	
30	0·50	0 78	83	

A Negative Optical Proof of the Absence of Seas in Mars.

By H. Dennis Taylor.

When occupied in reading a highly interesting article on the physical configuration of *Mars* in *Astronomy and Astrophysics* an idea suddenly struck me which seemed to me a valuable one —viz. that if there exist seas, or even water-covered spaces of moderate size, within the tropical regions of *Mars*, then we should expect to see a minute but brilliant reflection of the Sun in such water spaces whenever, by the diurnal rotation of the planet, they were brought into the proper angle to send us a solar reflection. I at once entered into a few simple calculations which satisfied me that the apparent brightness of this solar reflection, analogous to a reflection of the Sun from a thermometer bulb, would at least compare on fairly equal terms with the brightness of a 1st magnitude star. I then drafted a paper on the subject and submitted it to the March Council meeting of this Society, along with a note in which I said I could scarcely believe that its matter was entirely novel, and that the idea had not occurred to anybody before. At the same time I was not aware of any books on astronomy in which the important bearing of this question upon the physical state of *Mars* was even alluded to. Since then, however, one of the referees to whom my paper was submitted has kindly referred me to the memoir of Schiaparelli on *Mars* and to a paper dealing with this very question by Professor Phillips, of York, which, it seems, was published first in the *Proceedings of the Royal Society*, vol. xii. 1863. So that the claim for priority rests, I believe, with Professor Phillips. But until the other day I was quite ignorant of this, and the fact that the very same idea should afterwards recur to me, living in the same town, seems to suggest that there is something in ideas akin to certain epidemics. In the course of discussing the nature of the markings upon *Mars*, Professor Phillips wrote: "A positive proof of ocean on the disk of *Mars* would be afforded by the star-like image of the Sun reflected from the quiet surface or the more diffused light thrown back from the waves; but nothing of this sort has been placed on record." In a note he also wrote: "The quiet image here alluded to would not exceed $\frac{1}{20}$ of a second of angle at the opposition, if no allowance be made for irradiation." He then concludes by assuming it doubtful whether this star-like image would be visible except perhaps in very large instruments. But he enters into no calculation as to the apparent *brightness* of this "artificial star" as viewed from the Earth and as compared with other real stars.

Then Professor Schiaparelli, in his beautiful and elaborate memoir on *Mars* during the opposition of 1877, took up the subject again as being of the very highest importance. While expressing himself as very doubtful as to whether the darker

markings of *Mars* are to be regarded as seas, he then passes to the consideration of what he seems to consider the most powerful argument against their existence. I will here give a condensed translation of his method of dealing with the question. His figures are in practical accordance with what I have myself arrived at as most probable.

"It is certain," he says, "that if *Mars* were a polished sphere, capable of reflecting, in the fashion of a speculum, the solar rays, we ought to see a very minute image of the Sun glittering on his disc in the form of a star, and at a position easy to assign at each moment. Assuming the reflection to be total, it is easy to calculate the intensity of this image, given the diameter of *Mars* and its distance from the Earth and Sun. For example, in the opposition of 1877 attained on September 5, *Mars* being at the distance of 1·383 from the Sun and about 0·377 from the Earth, the image in question ought to figure as a star of a diameter of $\frac{1}{24}$ of a second of arc, and therefore of a brilliancy equal to $\frac{1}{2,100,000,000}$ of that of the Sun at distance 1. Now Professor Zöllner has estimated the total light reflected to us from *Mars* in mean opposition to be $\frac{1}{6,994,000,000}$ of that of the Sun at unit distance. From this it follows that in the opposition of 1877 the total luminosity of *Mars* was $\frac{1}{2,990,000,000}$ of that of the Sun at distance 1. Therefore, assuming total reflection, the minute solar image reflected from the polished surface of *Mars* would surpass in brilliancy the whole of the light from his disc. However, great allowance must be made for the low reflective power of a liquid like water, whose index of refraction being only $\frac{4}{3}$ would imply a reflective power for approximately perpendicular incidence of about $\frac{1}{49}$ part. Then allowance must be made for the absorption due to the double passage of the solar rays through the Martian atmosphere. Assuming the absorption to be as great as in the case of our own atmosphere, the above fraction ought to be reduced to about one-half, or in round numbers $\frac{1}{100}$. On this supposition, then, we should have for the luminosity of the reflected image

$$\frac{1}{21 \times 10^{10}}$$

of that of the Sun. But Zöllner has estimated the brightness of *Capella* to be

$$\frac{1}{5{\cdot}57 \times 10^{10}}$$

of that of the Sun. So that on 1877 September 5 the image of the Sun reflected from the convex mirror formed by any seas in *Mars*

ought to have appeared of a brightness equal to about one-fourth of that of *Capella, and therefore as a star of the 3rd magnitude.*"

The last words in my own italics are remarkable as seeming to show that Professor Schiaparelli regarded *Capella* as of the 1st magnitude, whereas measurements have made it of zero magnitude, or two and a half times as bright as an average 1st magnitude star. Therefore Professor Schiaparelli's magnitude 3 ought to read as magnitude 1·5. He then goes on to say that "Such a star could not possibly escape observation if occurring upon any of the darker areas of *Mars*, in spite of the undoubted influence which the surrounding bright surface of the planet would have to drown its splendour. But very slight inequalities in the surface of the water, in the shape of waves, would be enough to break up the clear united reflection into an infinitude of minute reflections. Now it is true that the sum of the luminous values of these reflections would not turn out much different to the single image, but the light would be spread over a larger space, and the amount of extension would depend upon the form of the waves and the inclination of their sides to the horizon. The formation of rugged crests would destroy any real image, and the nebulous patch of light having but a fraction of the luminous value of the light from the disc, might easily escape observation." Seemingly, then, Professor Schiaparelli concludes that the solar reflection could only fail to be visible to a spectator on the Earth armed with a good telescope, by reason of the water areas of *Mars* being in a rough and turbulent state.

But it would have to be assumed that the Martian water surfaces are *always* rough, and have always been rough ever since the invention of the telescope, which supposition is, I venture to think, quite untenable, if not ridiculous, in face of all we know about our own oceans, lakes, and rivers, and also certain facts, more clearly established of late, with regard to the behaviour of the so-called seas of *Mars* and the density of the Martian atmosphere.

Before returning to the discussion of the question, of the utmost degree of roughness allowable in the water areas of *Mars* consistently with the visibility of the solar reflection, I propose to slightly supplement Professor Schiaparelli's calculations of the brightness of the solar reflection by a different method.

Such various determinations have been arrived at by different observers as to the stellar magnitude of the Sun, or the ratio between its apparent luminosity and that of a star of zero magnitude like *Vega* or *Capella*, as to raise some doubts as to the degree of accuracy to be assigned to the above calculations, although the photometric estimates of the Sun's brightness arrived at by Zöllner certainly seem to accord fairly well with the apparent brilliancy of the planets.

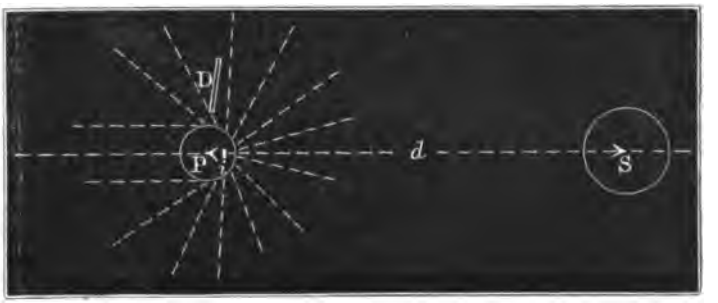


Fig. 1.

In fig. 1 let S be the Sun of a radius R, P a polished sphere of radius r illuminated by S at the distance d separating centres of S and P. And let D represent a disc, also of a radius r equal to that of P, which is placed at the same distance d from S, and illuminated perpendicularly by the latter. Let the surface of D be supposed to be of a pure white light-scattering character, reflecting irregularly all the light which falls upon it, and also let P be supposed to reflect, as a convex speculum, all the light which falls upon it. In other words, let their albedoes = 1 in both cases. Then it is obvious that D and P receive equal amounts of light from S, and since they reflect it all off again, in one case by irregular reflection, and in the other case by specular reflection, I was misled at first into supposing that, to an observer situated at any point on the line P - - - S, the point of light seen by reflection on P must be equal in total intensity to the total intensity of the light received from D.

But a little consideration is quite sufficient to throw doubt upon such a conclusion, for the disc D throws all the light back through an angle of 180° to the front of itself, and cannot throw any light behind its own plane, but the light reflected from the polished sphere P is reflected off through an extent of angle of 360°, and this distribution of light through greater angle must necessarily be at the expense of intensity of reflection through the forward 180°, and most likely also at the expense of intensity of the reflection in the direction of P - - - S. However, this can be easily put to the test of more exact calculation.

Let

B = intrinsic brightness of globe S

R = radius of globe S

d = distance representing centres of D or P and S.

Then the apparent intrinsic brightness of D, having an albedo = 1, will be

$$B\frac{R^2}{d^2}.$$

If now L represents the total apparent brightness of S as viewed from a standard distance d, then the apparent total brightness of D as viewed from S (at the same standard distance d) will be equal to

$$L\left(\frac{R}{d}\right)^2\left(\frac{r}{R}\right)^2 = L\left(\frac{r}{d}\right)^2.$$

Turning now to the case of the polished sphere P we have a miniature image of S formed at i halfway between the centre and periphery of P, and this image subtends the same angle at the centre of P as does the real source of illumination S, and also, by a well-known law of optics, the intrinsic brightness of this miniature image is the same as that of the original S. Therefore the apparent total brightness of the image i as viewed from the standard distance d will be equal to

$$L\left(\frac{\frac{1}{2}r}{d}\right)^2 = L\left(\frac{r}{d}\right)^2 \cdot \frac{1}{4}$$

or one-fourth of the value found for the light from the disc.

I have verified this theorem by a few simple experiments, as follows. A thermometer bulb full of mercury, the diameter of the mercury globe being ·485 inch, was compared with a disc of white paper of the same diameter, both being illuminated from the same source and viewed from a point 20 to 30 feet away. In fig. 2 C is a candle flame, S an opaque screen, B the mer-

Fig. 2.

cury bulb, D the disc of white paper, and O the position of observation, not less than 20 feet from C or D. The disc was placed to perpendicularly face the light, and both disc and bulb placed as closely as possible to the line of observation C - - - O. The observations were of course made in a darkened room. At the distance C - - - O the disc and bulb presented no very sensible diameter. Then, being short sighted, the light both from the disc and from the specular reflection of the candle flame in the bulb were spread out into a penumbra on my retina, and by a further voluntary shortening of the focus of my eye I could swell out the two lights to be compared, D and B, into two slightly overlapping discs whose apparent diameters so far exceeded the apparent real diameter of D as seen from O as to render the correction due to the greater area of D as small as possible. As the penumbras were generally made to be about ten times the apparent diameter of D, then the areas of the two

apparent lights became 10^2 for D and 9^2 for B, or about 5 to 4. B was placed at from $1\frac{1}{2}$ inches to 3 inches from the candle in different experiments, and then the disc D was adjusted to that distance from the candle found necessary to make the penumbras from the two lights appear of equal intensity as viewed from O.

In three experiments equality was attained when the ratios of the squares of the distances of B from C and D from C respectively were 1 : 3·6, 1 : $4\frac{1}{4}$, and 1 : 3·36.

In another case, with a different mercury bulb in use, the ratio came out about 1 : 4. With 1 to 3, D appeared slightly but distinctly the brightest; with 1 to 5·7 B was distinctly the brightest.

In two other cases a bulb of freshly polished speculum metal of ·37 diameter was tried against a disc of pure white paper of the same diameter, and the results again averaged 1 to 4 or rather under. Zöllner estimated the albedo of white paper to be ·70 (*Photometrische Untersuchungen*, p. 273) and mercury ·65, while Lord Rayleigh has estimated the albedo of mercury to be ·75 at nearly perpendicular incidence (*Phil. Mag.*, October 1892); so I think it will be fair to assume the albedoes of the bulb and of the white paper about equal, or perhaps the reflective power of the mercury slightly lower owing to it being encased in a thin glass bulb. A careful comparison of the two mercury bulbs used and the speculum bulb, as regarded their power of reflecting a sheet of white paper, showed no sensible difference, and speculum metal has been estimated by Sir John Conroy and others to prove an albedo varying between ·60 to ·70. These simple experiments, while not pretending to great accuracy, certainly confirm the theorem that the light reflected back from a polished sphere along the direction of illumination is one-fourth of the light reflected back in the direction of illumination from a disc having the same diameter and perpendicularly illuminated by the same source at the same distance, and supposing the two albedoes are equal. We next have to consider the modification of the amount reflected back when a spherical light-scattering surface is substituted for the flat light-scattering surface of the disc, the diameter of course remaining the same.

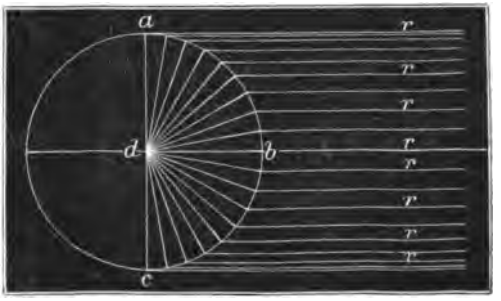


Fig. 3.

Let r, r, r, &c., in fig. 3 be parallel rays from the distant source of illumination falling upon the sphere a, b, c. Instead of a disc a - c receiving all these rays at perpendicular incidence, we must treat the surface of the hemisphere as cut up into a number of equal zones having their edges parallel to the plane or disc a - - c and having the common axis d - - b, which zones get illuminated at different degrees of incidence, and whose apparent widths and areas as viewed from the direction r - - r show large variations.

If the quadrant a - d - - b is divided into n equal parts, and the area of the base (or disc a - c) or $r^2\pi$ is supposed to equal 1 and to reflect light equal to 1 along the direction d - - r, then we have the sum of the following series as representing the total apparent luminosity of the whole hemisphere as viewed from a distant point on d - - r :

$$r^2\pi\left[\left\{1-\sin^2\left(\frac{n-1}{n}\right)90^\circ\right\}\cos\left(\frac{n-\frac{1}{2}}{n}\right)90^\circ + \left\{\sin^2\left(\frac{n-1}{n}\right)90^\circ-\sin^2\left(\frac{n-2}{n}\right)90^\circ\right\}\cos\left(\frac{n-1\frac{1}{2}}{n}\right)90^\circ+\text{\&c.}.\right.$$

&c., to n terms. And, if $r^2\pi = 1$, the total value of the series is $\frac{2}{3}$. This agrees perfectly with Zöllner's two theorems ; first as to the apparent illumination of a sphere being equal to that of a cylinder of same radius but of a height equal to $\frac{2}{3}$ of the diameter of the sphere, and having its axis perpendicular to the direction of viewing and illumination ; and, second, the apparent illumination of a cylinder with its height *equal* to its diameter, and axis perpendicular to direction of viewing and illumination being equal to the apparent illumination of its circular base when perpendicularly illuminated. Therefore the apparent brightness of the solar reflection off water surfaces in *Mars* in terms of the total apparent brightness of *Mars* will be

$$\frac{3}{2}\cdot\frac{1}{4}\cdot\frac{a}{A}F$$

where

a = the albedo of water

A = the general albedo of *Mars*

and

F = that fraction of the total incident light which is left after two passages through the Martian atmosphere.

Here A and F are both uncertain factors. Zöllner gives ·267 as the general albedo of *Mars*, but Seidel gives only ·09 or so ; while Professor Pickering, as the result of careful photometric measurements of the relative brightness of *Mars* and *Saturn* when at or

near conjunction in 1877, came to the conclusion that the albedo of *Mars* was not more than $\frac{1}{4{\cdot}6}$ of that of *Saturn*. If, therefore, we suppose the albedo of *Saturn* to be as high as that of freshly fallen snow, which Zöllner estimated as ·78, then the albedo of *Mars* comes out ·17. I will in the above formula assume ·21 to be the correct albedo for *Mars*.

The albedo of water for all angles of incidence up to about 20° has been proved to be about ·021 (Lord Rayleigh, *Phil. Mag.*, October 1892), and I will assume the fraction of light left after two passages through the perpendicular thickness of the Martian atmosphere to be $\frac{2}{3}$, in view of the strong evidence existing to show that its atmosphere is considerably thinner than our own. Then the above formula gives a value of $\frac{1}{4\,1\,0}$ as the ratio between the intensity of the solar reflection from a water surface in *Mars* and the total brightness of the whole Martian disc. Now Zöllner's photometric measurements of the apparent brightness of *Mars* gave it a relative brightness as compared with *Capella* of 8 to 1 when *Mars* is in mean opposition. But *Capella* is of 0 magnitude, therefore *Mars* in mean opposition is of an apparent brightness equal to twenty times that of a 1st magnitude star. Therefore the solar reflection from water in *Mars* at mean opposition should have an apparent brightness equal to half that of a 1st magnitude star, or $\frac{1}{5}$ of *Capella*. Schiaparelli's calculations, as we have seen, made it out to be equal to $\frac{1}{4}$ of *Capella*, with *Mars* in close opposition.

But a star equal in brightness to half a 1st magnitude star is a brilliant and conspicuous object even in a 2-inch telescope. Here a simple experiment can be made very useful and suggestive. I took an empty thermometer bulb made of thin opal glass measuring 1·4 inches in diameter. This glass is of the ordinary refractive index of about 1·53 or 1·54, and is impregnated, especially towards the inner surface of the bulb, with some white light-scattering substance which gives the whole bulb a resemblance to a globe of milk. On comparing its albedo or light-scattering power with that of pure white paper it seemed rather inferior, so that I should judge the albedo of the bulb to be about ·5. But the polished *surface* of the bulb gave a specular reflection of the source of illumination, and the amount of light reflected in this way would be that usually reflected by a glass surface. Its specular reflection was compared with, and found equal in intensity to, that from the first surface of a crown glass lens whose other surface was backed up by white paper. For an index of 1·54 the amount reflected at approximately perpendicular incidences would be represented by Young's formula

$$\left(\frac{\mu-1}{\mu+1}\right)^2=\left(\frac{\cdot54}{2\cdot54}\right)^2=\cdot045.$$

And if any of the white light-scattering particles happened to lie in or upon the actual glass surface they would obviously diminish

the amount of light reflected regularly, so that $4\frac{1}{2}$ per cent. represents the utmost amount of the incident light which is regularly reflected. This white bulb was then placed in a dark room and illuminated by a candle flame placed six inches to a foot or more away and as nearly as possible in the line of sight, the flame being screened in the direction of observation. On receding to some distance a white globe was visible in which the minute image of the candle flame stood out boldly like a star, and this star was too conspicuous to escape naked-eye vision at a distance of 30 feet, where the bulb would subtend about 13 minutes of arc. Here the relation between the albedo of the white surface and the true glass surface giving the specular reflection was $\frac{\cdot 50}{\cdot 045}$, or about 11 to 1, whereas in *Mars* we concluded that the relation between the general albedo of its surface and the albedo of water was $\frac{\cdot 21}{\cdot 021}$, or 10 to 1; or 15 to 1 after allowing for an absorption of $\frac{1}{3}$ for the double passage of the solar rays through the Martian atmosphere. Therefore the two cases are not very materially different, and a magnifying power of about sixty on any good telescope, enlarging *Mars* to an apparent diameter of say 18 minutes, would be quite sufficient to render the solar reflection easily visible. Yet, however difficult it may be to suppose that the water surfaces of *Mars* are never calm enough to give a defined reflection of the Sun, it is nevertheless advisable to consider the effect of moderate waves upon the image. To *Mars* at mean distance the Sun subtends about 21 minutes of arc, and its image reflected off a spherical water surface in *Mars* would appear to lie halfway between the centre and circumference of the planet, and would subtend 21 minutes of arc at *Mars'* centre. Therefore the angular diameter of the solar image in *Mars* as viewed from the Earth at average opposition would be, if the water surface were still, represented by

$$\frac{d}{4}\theta$$

where d = the apparent diameter of *Mars* in seconds and θ = the circular measure of 21 minutes. This comes out only ·0275 seconds of arc, or so small that it would need a telescope of 15 feet aperture at least to show any appreciable disc.

The absolute size of the solar image in miles would be equal to one quarter of the Martian diameter multiplied by θ or $1050.\theta$; that is, about $6\frac{1}{2}$ miles. Therefore lakes as small as this, if they occurred within the Martian tropical zone, should be capable of throwing us an unimpeded reflection of the Sun. But $6\frac{1}{2}$ miles is far narrower than the finest of the so-called canals of *Mars*. But we have never seen any flash of sunlight from them. It must be remembered too that small sheets of water are not so likely to be troubled with waves as oceans, and even if perturbed, subside again into calmness much sooner.

Let it be supposed, however, that the water surfaces were cut up into waves, whose sides at their greatest slope were inclined at an angle β to the Martian horizon. Then the effect would obviously be to spread out the solar reflection over an angular extent of the Martian surface equal to 2β. How much would it have to be spread out before it would quite escape scrutiny? This cannot be answered except in very general terms. Experiment leads me to think that an inclination of the steepest part of the wave to the horizon of about $14\frac{1}{2}°$ may be possible before the diffused patch of reflected light scattered over 29° of Martian surface would cease to be visible in a powerful telescope giving a large and bright image of *Mars*.

I took the same opal bulb as before, and, instead of illuminating it by a small candle flame, I illuminated it by a square sheet of white paper, reflecting the candle light on to the bulb.

In this way the ratio between the total light scattered by the opalescent substance of the bulb and the total light regularly reflected by the glass surface in the form of a broad patch of light (being a distorted image of the white paper) would not materially be disturbed, but instead of a luminous point, a broader and less intense image was formed. And I found that even when the sheet of paper was large enough to give a reflection in the bulb equal in apparent diameter to one-fourth of the apparent diameter of bulb, the approximately rectangular patch of light showed up in a quite noticeable manner against the duller background. And I do not see any reason for supposing that the effect would be essentially different, if, instead of diffusing the illuminant itself, we diffuse the image of that illuminant by the presence of corrugations on the reflecting surface, having a maximum inclination of sides to the horizon of $14\frac{1}{2}°$, whose sine is $\frac{1}{4}$.

But such waves as these are only what would occur in a fairly rough, if not a very rough sea. Shallow seas do not develop great waves so readily as deep ones, and what waves do arise soon subside again. Some recent telescopic observations of *Mars*, made under the most favourable atmospheric conditions prevailing at the loftily situated observatories in America, notably Mr. Percival Lowell's observatory in Arizona, certainly confirm very strongly the great variability in the outlines and depth of colour of the so-called seas of *Mars*. One cannot read Mr. Percival Lowell's articles on *Mars* in *Astronomy and Astrophysics*, detailing the great changes which he observed to take place as the summer advanced in the southern hemisphere of *Mars* during the late opposition, without being struck by the fact that the darker greenish markings of the disc, from being scarcely discernible and of generally small extension at the spring equinox, develop steadily both in depth of tint and extension to a most marked degree until what we have every reason to regard as the hottest part of the Martian summer is past, when they shrink in size and fade in colour until in the autumn

they have again relapsed into comparative obscurity. And this takes place in an even more marked degree in the case of the "canals."

If these dusky markings are really seas, then it is very obvious that they must be for the most part extremely shallow, or their extraordinary variations in area cannot be accounted for. And if shallow, then we have little reason for supposing them to be generally much agitated. Besides, even supposing that the atmosphere of *Mars* contains as much gas per square mile of surface as our Earth does, yet its density or pressure would be only two-fifths of that of our atmosphere, while its vertical movements under variations of temperature would have to take place on many times the scale of our Earth in order to produce the same amount of cooling and storm-generating effect. And, although the weight of water would be only two-fifths, yet its inertia and internal friction would be the same as with us, while, for a given wind velocity, the wind *pressure* would be considerably less than with us. Altogether it is extremely probable that the atmospheric disturbances of *Mars* are very mild affairs compared with our own. Mr. E. W. Maunder has very ably discussed the question of the climate of *Mars* in *Knowledge*, vol. xv., and arrived at much the same conclusion. We have therefore good reason for expecting any water surfaces existing on *Mars* to be generally in a calmer state than on our own planet.

Yet it is a very common thing in the case of our own sheets of water to see the Sun's image reflected with no greater unsteadiness than will cause oscillations of its image through five to ten times its own apparent diameter, and this amount of movement would, in the case of the Martian solar reflection, make no perceptible difference to the image as seen in an 18-inch refractor; it would still appear as a star.

Now some of the most well-marked "seas" of *Mars* happen to be well situated for sending us reflections when the Martian South pole is tilted towards us during a favourable opposition, like last year's! From Schiaparelli's *Mare Cimmerium* (longitude 200) eastwards to the E. border of the *Aurorœ Sinus* (longitude 60) for 220 degrees of longitude altogether, there is an only slightly interrupted series of so-called seas within a belt lying between 20° and 30° of South latitude, and therefore coming about Martian midday into the plane containing the centres of the Sun, *Mars*, and the Earth. But not a trace of a glint seems to have ever been observed.

The Martian atmosphere cannot be supposed to appreciably interfere with the visibility of the solar reflection, if it exists. I have allowed for an atmospheric absorption of one-third of the light in the above calculations. For, while the planet's atmosphere may absorb more or less light in the sense that glass does, yet we cannot suppose that it also scatters and diffuses light, and thus interferes with the definition of details seen

through it, as our own atmosphere does on a hazy day. For, during the summer, at any rate, of *Mars*' southern hemisphere, the visibility of such extremely fine details as the more difficult "canals" of *Mars* is fairly constant, and depends altogether upon our own atmospheric conditions being favourable.

The dark zone which so closely follows up the retreating edge of the S. polar cap of *Mars* as the summer advances, has usually been considered to be a belt of water resulting from the thawing of the polar snows. But what proof have we that the white polar cap consists of snow of sufficient depth to cause such extensive inundations as would be indicated by the dark-greenish areas lying around the S. pole, supposing they are water surfaces? The rapid melting and shrinkage, and in some cases total disappearance, of the polar snows each summer, is in itself strong evidence of the small depth of the snow deposit (or hoarfrost deposit, or whatever it is), for the efficiency of the Sun's heat for melting snow in *Mars* is barely a half of what it is with us. If we suppose,* then, that the dark-greenish areas which develop and spread in the S. polar regions of *Mars* as the summer progresses are really sheets of water resulting from the thaw, we must obviously assume a most extraordinary degree of flatness in the surfaces inundated, for we could not assume more than two or three feet of depth of water on the above hypothesis, as the greenish areas around the pole far exceed the area of the snow cap, which in itself cannot be more than a few yards thick.

The hypothesis which, I venture to think, best accords with the facts is suggested by the case of our own Earth, where a zone of revivifying vegetation of a dwarf character closely follows up the melting of the snows which have formed a temporary extension of the true polar ice cap during the winter. It is this zone of vegetation, within and about the Arctic circle, which annually becomes the principal breeding ground of a very large number of migratory birds, who find their food either in the herbage and vegetation itself or else in the insects, &c., which live among it. Such a zone existing in *Mars* could scarcely escape observation as a region of a darker and more greenish colour than the rest of the surface. And, seeing that we have negative proof of the fact that the areas having the same colour and appearance, but lying within the planet's tropical regions, are not water surfaces, we may assume as most likely that the greenish colour of all the darker markings of the planet is caused by the presence of vegetation growing in the more low-lying regions where there is sufficient moisture existing in the soil, while the brighter and ruddy-tinted regions are barren desert. The observed seasonal changes in the markings would thus be accounted for.

The Rev. Edmund Ledger, in a recent lecture, discussed the

* Obviously, we could not apply the test of presence or absence of a solar reflection to sheets of water outside the tropical regions of the planet.

absurdity of supposing that the canals could be looked upon as artificial waterways in themselves, for they must be at least 20 miles in diameter to be discerned at all, but he suggested that they might indicate the lines of canals, the visible broadening out being due to cultivated tracts on either side of the main waterway, which should show a darker and greenish tinge. But, if not canals, they might indicate the lines of roads cut straight across the deserts from one centre of population to another. It would be obviously the aim of any inhabitants to make the roads as straight as possible in a nearly waterless planet. Then, if tracts of country were cultivated and made to support vegetation, surely the districts immediately surrounding the centres of population (the dots seen where the canals intersect) would first be attended to, and afterwards substantial strips of desert at each side of the roads would be reclaimed and covered with vegetation. This is one hypothesis which might help to explain the suspiciously artificial-looking and designed appearances of the so-called canals of *Mars*.

The remaining question, of the relative brightness of the solar reflection when *Mars* is in other positions than in opposition, may be shortly dealt with ; for the relative configuration of the orbits of the Earth and *Mars* is such that two lines, one joining the Sun and *Mars* and the other joining the Earth and *Mars*, never enclose a greater angle than about 50°, so that the maximum angle of incidence and reflection would be 25°. But it has been proved that the percentage of light reflected from water at that angle is not very appreciably greater than that reflected perpendicularly. The contrast between the solar reflection and the gibbous disc of *Mars* would thus remain much about the same as when in opposition.

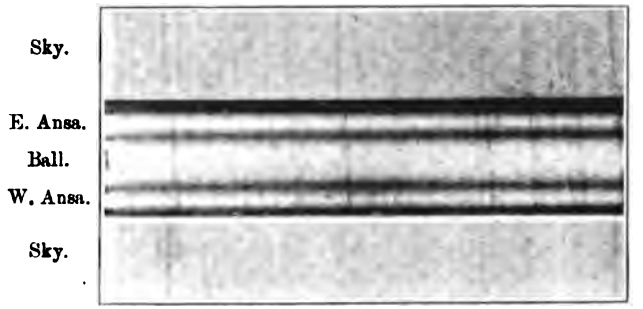
Photographs of the Spectrum of the Ball and Rings of Saturn.

(*Letter to the Secretary.*)

E. W. Maunder, Esq.,
Secretary of the Royal Astronomical Society,
London, England.

Dear Sir,—I send you with this a photograph of the spectrum of *Saturn*, which it may interest some of the Fellows of the Society to examine. The fact that the lines in the spectra of the ansæ do not follow the direction of the planetary lines, but are very slightly inclined in the opposite direction, is a spectroscopic proof of the meteoric constitution of the ring, as I have explained at length in the May number of the *Astro-physical Journal*. Although the positive enlargement which I send is less satisfactory than the original negative viewed under a microscope, the feature mentioned above can be seen without difficulty.

To prevent the eye from being influenced by the slope of the planetary lines, it is best to cover the central spectrum with a narrow slip of paper.



Spectrum of Saturn, 1895 April 19.
Enlarged 15 diameters from the original negative taken at the Allegheny Observatory, by J. E. Keeler.

The large relative displacement of the planetary and sky spectra is due to the fact that the comparison spectrum was photographed the next morning after the exposure to the planet, and at a quite different temperature. It does not affect the value of the photograph for this particular purpose. The exposures were, *Saturn* 2 hours, and sky 4 minutes. As the sky spectrum was too dense, a bar was placed across the plate during part of the exposure (in making the positive), and some horizontal markings resulted, which are not on the original negative.

Yours very truly,

JAMES E. KEELER.

Observations of Jupiter. By W. F. Denning.

The following are a few results of observations of *Jupiter* made between 1894 November 5 and 1895 May 10 with a 10-inch reflector, powers 252 and 312.

The red spot was seen on several occasions, but it was extremely faint, especially at its preceding end. Its south side appeared to be connected with a grey belt. Between 1894 November 25 and 1895 May 10 I found a mean period of

$9^h\ 55^m\ 41^s{\cdot}2$ (401 rotations).

This is slightly more ($0^s{\cdot}6$) than the period ($9^h\ 55^m\ 40^s{\cdot}63$) on which Mr. Marth's zero meridian System II. is based, and it

agrees exactly with the rate I derived from the preceding opposition. According to my last observation on 1895 May 10 the spot followed the zero meridian 8 minutes, so its longitude was 4°·9.

In north latitude about 35° there has been visible a narrow, dark, broken belt, and black spots have sometimes been seen upon it. I watched two of these objects between 1894 December 4 and 1895 January 28, and determined their periods as follow :—

	h	m	s	
(1)	9	55	39·5	(118 rotations)
(2)	9	55	38·5	(„)

The mean of the pair is $9^h\ 55^m\ 39^s$, or $2^s{\cdot}2$ less than that of the red spot. The markings on this northerly belt would therefore occupy about 18 years in completing one revolution of *Jupiter* relatively to the position of the red spot.

The great north equatorial belt is double, and its north side has exhibited a very disturbed condition in recent years. A numerous array of white and dark spots are dispersed along the belt in an irregular manner. I obtained the times of transit of many of these objects, and the resulting periods of five white and four dark spots are as follow :—

White Spots.				*Black Spots.*			
h	m	s		h	m	s	
9	55	37·7	(406 rotations)	9	55	37·8	(447 rotations)
9	55	37·1	(249 „)	9	55	36·8	(389 „)
9	55	36·6	(389 „)	9	55	32·2	(63 „)
9	55	34·4	(442 „)	9	55	31·0	(254 „)
9	55	31·3	(104 „)				

The motions of the spots differ in individual cases, and the rate of the same objects is not consistently maintained during a long interval. The fluctuations of speed are too great to be satisfactorily accounted for by errors of observation. It will be seen from the list that the rotation period as derived from the different objects varies to the extent of $6^s{\cdot}8$, the time ranging from $9^h\ 55^m\ 31^s$ to $9^h\ 55^m\ 37^s{\cdot}8$. The mean of all is $9^h\ 55^m\ 35^s$, or $6^s{\cdot}2$ less than the period of the red spot.

With reference to equatorial spots not many conspicuous examples were observed in 1894 November and December, but in 1895 January they became numerous. Ill-health and interruptions from cloudy weather, however, prevented my following them up with sufficient closeness to get good rotation periods, as the objects varied rapidly in appearance, and it was not easy to identify them. In March I observed a white and black equatorial spot for several nights as follow :—

	White Spot on C.M.	Dark Spot on C.M.	Interval.
	h m	h m	m
March 22	8 47	9 2	15
24	10 4	10 15	11
31	9 27	9 35	8

The dark spot was rapidly gaining on the white, and on April 5 and 7 I looked for the objects again, but the aspect of the region had quite changed, apparently by the blending of the two spots. I obtained observations on succeeding nights, thinking it possible the dark spot might reappear to the west of the white one, but I failed to recover either of the objects with certainty.

Saturn.—During the first half of May I made observations of this planet on ten nights with a view to detect spots on the equator or belts. I employed one of Steinheil's "monocentric micrometer oculars" of $\frac{1}{4}$ inch equivalent focus (= power of 312), but detected no irregular markings on the disc. There was a narrow dark belt near the equator and a broad diffused band of shading in the north hemisphere, but no other details could be made out with the means employed.

Bristol: 1895 *May* 20.

Diameters of Jupiter and his Satellites observed at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Diameters of Jupiter.

The following measures were made with the 28-inch refractor during the past winter. They were commenced on 1894 November 23, but the bad weather and frost prevented any work from 1895 February 5 to March 12, so that the series is not as complete as was wished. The diameters are reduced to mean distance 5·2028 (Leverrier), and the equatorial diameters are corrected for phase from Mr. Marth's Ephemeris, published in the Society's *Monthly Notices*. The following table exhibits the results found by each observer, in separate columns, and also distinguishes between the diameters obtained with different eye-pieces, those with the powers 450 and 470 being grouped together. It will be seen that there are indications of personality and also of a difference due to the power of the eye-piece employed.

Diameters of Jupiter.

Date. 1894.	Power of Eye-piece.	Mr. Dyson. Equat. Diam.	Mr. Dyson. Polar Diam.	Mr. Maunder. Equat. Diam.	Mr. Maunder. Polar Diam.	Mr. Lewis. Equat. Diam.	Mr. Lewis. Polar Diam.
Nov. 23	470	...	...	...	...	38·853	36·306
Dec. 18	470	39·052	36·308	...	...	38·889	36·120
1895. Jan. 1	670	38·494	36·175	...	...	38·610	36·124
9	470	...	...	...	...	37·860	35·827
18	670	...	...	37·977	...	...	...
20	450	39·169	36·511	...	...	...	...
21	450	39·435	36·625	...	...	...	...
22	670	...	...	...	...	37·791	35·753
26	670	...	...	...	...	37·931	35·783
Feb. 5	450	...	...	38·605	36·136	...	...
Mar. 12	670	...	...	...	...	37·618	36·143
13	670	...	...	...	...	37·483	35·880
17	670	38·521	36·184	...	..	...	...
18	670	...	...	...	...	38·411	35·553
22	670	...	...	...	...	38·103	35·922
26	670	...	...	...	...	38·356	...
31	670	38·981	36·352	...	. .	...	...
Apr. 1	670	...	...	...	...	38·179	36·146
3	670	...	...	...	...	38·228	36·029
Mean	450	39·219	36·481	38·605	36·136	38 534	36·084
Mean	670	38·665	36·237	37·977	...	38·071	35·926
(450)–(670)		+0·544	+0·244	+0·628	...	+0·463	+0·158
Mean Diameter		38·942	36·359	38·291	36 136	38·303	36·005
Ellipticity			$\frac{1}{15·1}$		$\frac{1}{17·8}$		$\frac{1}{16·7}$

Using the observations of all three observers, the resulting equatorial diameter is 38″·407, the polar diameter 36″·099, and an ellipticity of $\frac{1}{16·64}$.

Professor E. E. Barnard, with the 36-inch Lick refractor, obtained for the equatorial diameter 38″·522, and polar diameter 36″·112.

Diameters of the Satellites.

The equatorial and polar diameters of the satellites were made in January and March of this year, the plan of the work being to obtain a long series of both diameters taken on the same evening with the view of detecting any possible ellipticity. To avoid any prejudice, the equatorial diameters of all four were measured before making the measures for the polar diameters. A very complete series has been obtained, notwithstanding the break in February, above mentioned, and the observations on the whole indicate a slight prolate ellipticity in J I. and J II., the polar diameters being the larger. In the table the column (E – P) gives the difference of the two diameters on each evening, the sums of the positive and negative residuals, and the mean difference.

Equatorial and Polar Diameters of Jupiter's Satellites. Collected Results.

Date.	Obser-ver.	Power.	Equat. Diam.	J I. Polar Diam.	E−P.	Equat. Diam.	J II. Polar Diam.	E−P.	Equat. Diam.	J III. Polar Diam.	E−P.	Equat. Diam.	J IV. Polar Diam.	E−P.
			″	″	″	″	″	″	″	″	″	″	″	″
Jan. 1	L.	670	1·131	1·126	+0·005	0·856	0·964	−0·108	1·814	1·315	+0·499	1·582	1·129	+0·453
9	L.	470	1·090	1·122	− ·032	0·710	0·74	− ·033	1·478	1·362	+ ·116	1·314	1·429	− ·115
21	D.	450	...	...	...	...	...	...	1·286	...	...	...	...	...
22	L.	670	1·027	1·053	− ·026		1·064	− ·126	1·300	1·416	− ·116	1·340	1·438	− ·098
26	L.	670	0·835	0·989	− ·154	0·872	0·919	− ·047	1·271	1·276	− ·005	1·308	1·343	− ·035
Mar. 12	L.	670	0·796	0·775	+ ·021	0·742	0·726	+ ·016	1·247	1·325	− ·078	0·996	1·018	− ·022
13	L.	670	0·915	1·139	− ·224	0·874	1·050	− ·176	1·271	1·608	− ·337	1·342	1·187	+ ·155
17	D.	670	1·333	1·164	+ ·169	...	...	...	...	...	...	...	...	...
18	L.	670	1·083	1·356	− ·273	0·946	1·274	− ·328	1·793	1·857	− ·064	1·446	1·558	− ·112
22	L.	670	0·950	0·991	− ·041	0·932	0·971	− ·039	1·482	1·624	− ·142	1·434	1·498	− ·064
26	L.	670	1·051	1·236	− ·185	1·181	1·085	+ ·096	1·548	1·339	+ ·209	1·403	1·511	− ·108
31	D.	670	1·359	1·318	+ ·041	1·160	1·176	− ·016	...	...	...	1·378	1·360	+ ·018
Mean Diameters			1·052	1·115	+ ·236 − ·935	0·921	0·997	+ ·112 − ·873	1·449	1·458	+ ·824 − ·742	1·354	1·347	+ ·626 − ·554
Mean Diameter			″ 1·084		″ − ·063	″ 0·959		″ − ·076	″ 1·454		″ + ·009	1·350		″ + ·007

For comparison the following are appended :—

			J I.	J II.	J III.	J IV.
			″	″	″	″
1880	Chicago,	18½ inch	1·114	0·980	1·778	1·457
1893	Lick	36 „	1·048	0·870	1·521	1·430
1895	Greenwich	28 „	1·084	0·959	1·454	1·350

Royal Observatory, Greenwich :
1895 *June* 11.

On a Fixed System of Star Coordinates.

By R. H. M. Bosanquet, F.R.S.

Polaris is taken as pole of a system of coordinates. The distance of any star from *Polaris* is one coordinate (D). Great circles are drawn through *Polaris* and other stars, one of which (*ε Orionis*) is taken as starting-point. The angle at *Polaris* between any of these great circles and the one through *ε Orionis* is the other coordinate, and is called the ascension (A).

If consistent positions of the stars concerned are given in any system of coordinates, the *Polaris* distance and ascension can be found. Where the given places are equatorial, the work has been reduced to the determination of small quantities for stars of moderate declination; and the calculation can be carried to the third decimal of 1″ with ordinary logarithms by a short process.

The following places of *Spica* are from a list reduced from the various catalogues. The annual change is by comparison with the Bradley place; the number for 1900 by the annual change.

α Virginis.

Mean Places.	A. 117° 12′	Annual Change.	1900.	D. 101° 51′	Annual Change.	1900.
	″	″	″	″	″	″
Auwers' Bradley, 1755	50·16	...	...	51·67	...	...
Greenwich, 1880 ...	43·90	−0·050	42·90	54·79	+0·025	55·29
Radcliffe, 1890 ...	43·05	−0·053	42·52	54·23	+0·019	54·42
Nautical Almanac, 1895	43·18	−0·050	42·93	55·08	+0·024	55·20

The annual changes form the basis of a discussion of proper motions. The selection of *ε Orionis* is connected with this.

As to the places of the list for 1900. The *Nautical Almanac* places agree with the Greenwich, as they should. The Radcliffe and Greenwich have little or no average difference in A; but the Greenwich *Polaris* distances are always in excess of the Radcliffe.

The same method could be applied directly to the results of observation corrected for refraction and aberration, and interpolated to the same time, if it were not for the insufficient accuracy of single observations of the fundamental stars.

As to the origin of ascension, secondary fundamental stars could be used, which would, in fact, be identical with the clock stars for the most part.

For *Polaris* additional material must be obtained, either by co-operation or observation out of the meridian, or both.

Errors in *Polaris* R.A. affect the results very little.

Assuming that sufficiently accurate places of *Polaris* can be got, the numbers obtainable through the calculations indicated will be directly comparable, as in the above example, without the intervention of precession or nutation.

Two methods are suggested for extra-meridian observations:—

(1) A fixed instrument for observation of *Polaris*, by means of which continuous observation of high accuracy would be possible.

(2) A transit instrument in a plane through the pole at right angles to the meridian.

The different historical values of the precession are summarised.

The values which have been attributed to the proper motion of *Polaris* in connection with the different precessions are exhibited in a comparable form in *Polaris* coordinates.

Places of the pole of the ecliptic and of the pole are given in *Polaris* coordinates for different dates; also a simple approximate method of dealing with the motion of the pole.

Suggestions are made for the tabulation of the functions which connect two systems of spherical coordinates, whose poles are not far apart, both in connection with the application of the above system to particular stars and as a more general question of spherical geometry.

Note.—The above is a summary of the chief contents of a paper, bearing the same title, which is to be placed in the library of the Society, together with a supplementary paper entitled "On the Star Survey by Fixed Coordinates in the Southern Hemisphere; with a Proposal for Cooperation."

On the Relation between Precession and Proper Motion.
By R. H. M. Bosanquet, F.R.S.

My former paper on a fixed system of star coordinates was based to some extent on the idea that, as changes in the adopted precession had been found desirable in the past, the same might happen in the future. I therefore saw with interest Mr. Stone's paper on the places of Eight Close Southern Polar Stars (*Monthly Notices*, LV., 299), where the argument is that the precession must be right because the residual proper motions are so small.

Now I have for some time been aware that the proper motion of *Polaris* is susceptible of diminution by an increase of the adopted precession; and it occurred to me in examining σ *Octantis*, as a possible pole of a southern star survey, to discuss the proper motion from this point of view. The result is that the proper motion of σ *Octantis* is also susceptible of diminution by an increase of the adopted precession; and the values of the increase of precession required to make the proper motion a minimum are similar in the two cases.

On the other hand 51 *Cephei* (Hev) requires a diminution of the precession, somewhat greater than the increase of the former cases, to make the proper motion a minimum.

These three stars form a system determining, by the combination of their minimum requirements, a precession differing not

very widely from that in use. And I propose to use them as illustrations in support of two propositions.

First, in the separate cases, certain large definite alterations in the precession cause no change in the magnitude of the resultant proper motions, while smaller alterations even diminish them.

Second, where the precession is considered with reference to a number of stars whose minimum proper motions require different precessions, large changes in the precession may produce very small changes in the average magnitude of the resultant proper motions within wide limits.

If these propositions are established, I think that no argument can be founded on the smallness of the proper motions to prove the precise exactness of the precession in use.

Every star has a minimum value for its proper motion, which occurs when the direction of the proper motion is along the great circle joining the star to the pole of the ecliptic. If the proper motion have any other direction, let it be resolved along, and at right angles to that great circle. Then a value of the precession can always be found, which shall absorb the component at right angles to the great circle, leaving the component along the circle as an irreducible minimum.

The process pursued in evaluating these quantities may be sketched as follows :—

A_ϵ is the angle at the star between any origin and the pole of the ecliptic.

A the angle between the same origin and the direction of the proper motion.

$A_\epsilon - A$ the inclination of the proper motion to the great circle through the star and the pole of the ecliptic.

$d\Sigma''$ is the resultant proper motion.

$d\Sigma'' \cos (A_\epsilon - A)$ component along circle to pole of ecliptic.

$d\Sigma'' \sin (A_\epsilon - A)$ component at right angles to circle.

D is the angular distance from the star to the pole of the ecliptic.

$\frac{d\Sigma'' \sin (A_\epsilon - A)}{\sin D}$ is the change of precession required for minimum proper motion.

$d\Sigma'' \cos (A_\epsilon - A)$ is the minimum proper motion.

In the case of *Polaris* the required data are taken from my paper "On a Fixed System of Star Coordinates," except the proper motion. I have reason to suppose, after examining Auwers' Bradley, that the discrepancy between the proper motion there found by comparison and the modern values, may be due chiefly

to the errors of the places of the Fundamenta. I therefore adopt the mean of the following values :—

Polaris.	$d\Sigma''$.	A of pole of motion, about Polaris, from ϵ Orionis.
	"	° ′ "
Auwers	0·0393	294 54 0
Greenwich, 1880 ...	0·0387	293 13 0
Radcliffe, 1890... ...	0·0381	293 59 0
Mean	0·0387	294 2 0
For direction of motion add		90 0 0
A from ϵ Orionis		24 2 0
A_ϵ from ϵ Orionis		184 38 0
D „		23 54 39

For the other stars a system of calculation was arranged.

Pole of the ecliptic.

A_ϵ, reckoned from the R.A. plane of the star, and D were found by formulæ of the same types as transformations I, II in my former paper.

Proper motion.

A, reckoned from the R.A. plane of the star, and $d\Sigma''$ were found as follows :—

$$(1)\quad \tan A = \frac{\sin \Delta d\alpha''}{d\Delta''} \qquad (2)\quad d\Sigma'' = \frac{d\Delta''}{\cos A}.$$

In the case of σ *Octantis* there was a slight difficulty. The proper motion assigned by Mr. Stone (*Monthly Notices*), lv. 299, is not there referred to any definite equinox. Assuming that the *Nautical Almanac* place for 1895 is correct (it is probably founded on Mr. Stone's calculations), I find the following proper motions for 1880 and 1895, through the medium of the *Polaris* places given in my paper on the "Star Survey by Fixed Coordinates in the Southern Hemisphere."* I now compare these proper motions with Mr. Stone's from the above reference :—

σ Octantis.	R.A.	N.P.D.
	"	"
1880	+1·049	+0·022
1895	+1·216	+0·020
Stone	+1·125	+0·02

* The *Polaris* proper motion was allowed for with the value given above, as well as the proper motion of ϵ *Orionis* in ascension, which is $-0''·027$ annually. Then the resultant of the remaining proper motion of the star was formed. The parallactic angle at the star between the *Polaris* and R.A. circles was found for the two dates, and the resultant proper motion resolved accordingly.

I used the numbers derived from the 1880–1895 comparison, taking everything with reference to 1880.

The proper motion and place of 51 *Cephei* (Hev.) were taken from the Greenwich Catalogue, 1880.

The value of ω employed for 1880 was

$$23^\circ\ 27'\ 17''.40.$$

The following numbers were found—

	σ Octantis.	51 Cephei (Hev.).
A_ϵ	174° 3′ 0″	170° 20′ 44″
A	148 54 0	− 29 37 40
D	24 10 34	26 46 16
$d\Sigma''$	0 0 0·0257	0 0 0·0586

The following table exhibits the results (SE is the great circle from the star to the pole of the ecliptic) :—

Resolution of Proper Motions along and at Right Angles to SE; and Changes involved by Reduction of Proper Motion to Minimum.

	Resultant Proper Motion.	$A_\epsilon - A$.	Minimum Component along SE.	Numerical Diminution of Resultant.	Change in direction.	Component Perpendicular to SE.	Change of Precession required for diminution to minimum.
Polaris	0″·0387	160° 36′	−0″·0365	0″·0022	−19° 4′	+0″·0129	+0″·0317
σ Octantis	0·0257	25 9	+0·0233	0·0024	+25 9	+0·0109	+0·0267
51 Cephei (Hev.)	0·0586	199 58	−0·0551	0·0035	+19 58	−0·0200	−0·0445
						Mean	+0·0046

Resultants for Changes of Precession.

Change of Precession.	+0″·0317.	−0″·0445.
Polaris	0″·0365	0″·0478
σ Octantis	0·0233	0·0373
51 Cephei	0·0650	0·0551
Average of resultants 0″·0410	0·0416	0·0467

The reduction to the minimum changes the direction of the motion through the angle, "change in direction."

The application of twice the "change of precession required, &c.," would bring back the numerical resultants to their original values; but they would be turned through twice the angle, "change in direction."

The "change of precession required, &c.," is, for *Polaris* and σ *Octantis*, about twice the difference between Bessel's last

number (III. of my paper "On a Fixed System, &c.") and the modern value (Struve). It is about three times that difference for 51 *Cephei*.

Therefore, in the cases of *Polaris* and *σ Octantis*, the resultant, after diminishing, returns to the same numerical value, when the precession is increased by four times the difference (Struve—Bessel, III.). In the case of 51 *Cephei* the diminution of the precession, after which the resultant returns to its original value, is about six times that difference.

As far as the separate stars go, therefore, my first proposition is amply proved, viz., that, in the separate cases, large definite alterations in the precession produce no change in the magnitude of the resultant proper motions, while smaller alterations even diminish them.

We now pass to the average magnitude of the resultant proper motions: this is given for the precession in use and for the precessions corresponding to the minimum proper motions of *Polaris* and 51 *Cephei*. This covers a range of five times the difference (Struve—Bessel III.), and the changes in the average magnitude of the resultants are very small.

There would, in a general determination, be cases of stars having their proper motions nearly at right angles to SE. In these cases only would a change of precession determine directly a commensurate change in the resultant proper motion.

I think I may now claim that my second proposition is established; that, when the precession is considered with reference to a number of stars whose minimum proper motions require different precessions, large changes in the precession may produce very small changes in the average magnitude of the resultant proper motions within wide limits; and, consequently, no argument can be founded on the smallness of the proper motions to prove the precise exactness of the precession in use.

Incidentally it appears that the best method of determining the precession from the proper motions of stars is the combination of the various precessions which determine the minimum proper motions of the stars concerned.

It is worth remark that circumpolar stars and other stars far from the ecliptic are unsuitable for the determination of precession, since the component at right angles to SE, by means of which the change of precession is found, is, in such cases, much less than the change of precession itself. Stars near the ecliptic are most suitable, as in these cases the component in question is nearly equal to the change of precession it determines.

Teneriffe: 1895 *May* 21.

Ephemeris for Physical Observations

Greenwich Noon.	Position-angle of ℒ's Axis. P	L−O	Diff.	B	Annual Parallax. A−L	Apparent Diameter. Equat. 2a	Defect.	Polar. 2b
1895.	°	°		°	°	″	″	″
Aug. 30	13·598	343·587	394	+1·051	−6·796	33·43	0·12	31·33
Sept. 1	13·750	343·981	389	1·035	7·026	33·53	·13	31·43
3	13·900	344·370	384	+1·019	−7·251	33·64	0·13	31·53
5	14·047	344·754	380	1·003	7·472	33·76	·14	31·64
7	14·192	345·134	375	0·988	7·688	33 88	·15	31·75
9	14·334	345·509	369	·972	7·899	34·00	·16	31·87
11	14·473	345·878	364	·957	8·104	34·13	·17	31·99
13	14·609	346·242	358	+0·941	−8·304	34·27	0 18	32·12
15	14·743	346·600	352	·925	8·498	34·41	·19	32·25
17	14·874	346·952	346	·910	8·687	34·55	·20	32·38
19	15·002	347·298	339	·894	8·870	34·70	·21	32·52
21	15·127	347·637	333	·879	9·046	34·85	·22	32·66
23	15·249	347·970	326	+0·864	−9·215	35·01	0·23	32·81
25	15·367	348·296	319	·849	9·378	35·17	·23	32·96
27	15·483	348·615	312	·834	9·534	35·33	·24	33·11
29	15·596	348·927	305	·819	9·683	35·50	·25	33·27
Oct. 1	15·705	349·232	297	·805	9·824	35·67	·26	33·44
3	15·811	349·529	288	+0·790	−9·957	35·85	0·27	33·61
5	15·914	349·817	280	·775	10·082	36·04	·28	33·78
7	16·014	350 097	272	·761	10·200	36·22	·29	33·95
9	16·110	350·369	263	·747	10·309	36·41	·29	34·13
11	16·202	350·632	255	·733	10·409	36·61	·30	34·31
13	16·291	350·887	245	+0·720	−10·500	36·81	0 31	34·50
15	16·376	351·132	236	.706	·583	37·01	·31	34·69
17	16·458	351·368	226	·693	·656	37·22	·32	34·89
19	16·536	351·594	216	·680	·719	37·43	·33	35·09
21	16·611	351·810	205	·668	·772	37·65	·33	35·29
23	16·682	352·015	196	+0·655	−10·815	37·87	0 34	35·49
25	16·749	352·211	185	·643	·848	38·09	·34	35·70
27	16·812	352·396	174	·631	·870	38·32	·34	35·91
29	16·872	352·570	162	·619	·881	38·55	·35	36·13
31	16·927	352·732	151	·608	·881	38·78	·35	36·34
Nov. 2	16·979	352·883	140	+0·597	−10·870	39·01	0·35	36·56

of Jupiter, 1895-96. By A. Marth.

Greenwich Noon.	Brightness in Star Magn.	Longitude of Ⅎ's Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O	B
1895.	m	°	°	°	m	°	°
Aug. 30	−1·45	83·43	311·62	+0·20	49·833	336·7944	+1·2083
Sept. 1	−1·45	38·94	251·86	·21	49·674	336·9582	1·2002
3	−1·46	354·45	192·11	+0·23	49·509	337·1220	+1·1921
5	−1·47	309·97	132·37	·24	49·339	337·2858	1·1840
7	−1·47	265·49	72·63	·26	49·164	337·4495	1·1759
9	−1·48	221·03	12·91	·27	48·984	337·6132	1·1678
11	−1·49	176·57	313·19	·29	48·798	337·7769	1·1597
13	−1·50	132·13	253·48	+0·30	48·608	337·9405	+1·1515
15	−1·50	87 69	193·78	·31	48·412	338·1041	1·1434
17	−1·51	43·26	134·09	·33	48·212	338·2676	1·1353
19	−1·52	358·83	74·41	·34	48·007	438.4311	1·1272
21	−1·53	314·42	14·74	·36	47 798	338·5945	1·1190
23	−1·54	270·02	315·07	+0·37	47·585	338·7579	+1·1108
25	−1·55	225·63	255·42	·38	47·367	338·9212	1·1027
27	−1·56	181·24	195·77	·40	47·146	339·0845	1·0945
29	−1·57	136·87	136·14	·41	46·920	339·2477	1·0863
Oct. 1	−1·58	92·50	76·51	·42	46·691	339·4109	1·0781
3	−1·59	48·15	16·89	+0·43	46·459	339·5741	+1·0699
5	−1·60	3·80	317·29	·44	46·224	339·7372	1·0617
7	−1 61	319·47	257·69	·45	45·985	339·9003	1·0535
9	−1·62	275·14	198·11	·46	45·743	340 0633	1·0452
11	−1·63	230·83	138·53	·47	45·499	340 2263	1·0370
13	−1·64	186·53	78·96	+0·48	45·252	340·3892	+1·0288
15	−1·66	42·23	19·41	·49	45·003	340·5521	1·0206
17	−1·67	97·95	319·87	·49	44·752	340·7149	1·0124
19	−1·68	53·68	260·33	·50	44·499	340·8777	1·0042
21	−1·69	9·42	200·81	·50	44·244	341·0404	0·9959
23	−1·70	325·17	141·30	+0·51	43 988	341·2031	+0·9876
25	−1·72	280·93	81·80	·51	43·731	341·3657	·9794
27	−1·73	236·70	22·31	·51	43·473	341·5283	·9711
29	−1·74	192·48	322·83	·52	43·214	341·6909	·9628
31	−1·75	148·28	263·37	·51	42·955	341·8534	·9545
Nov. 2	−1·77	104·09	203·91	+0·51	42·696	342 0159	+0·9462

Greenwich Noon.	Position-angle of ♃'s Axis. P	L−O.	Diff.	B	Annual Parallax. A−L.	Apparent Diameter. Equat. 2a	Defect.	Polar. 2b
1895.	°	°		°	°	″	″	″
Nov. 4	17·026	353·023	128	·586	·847	39·25	·35	36·79
6	17·070	353·151	117	·575	·813	39·49	·35	37·01
8	17·109	353·268	104	·565	·767	39·73	·35	37·24
10	17·145	353·372	92	·554	·709	39·98	·35	37·47
12	17·176	353·464	79	+0·545	−10·638	40·22	0·35	37·70
14	17·203	353·543	67	·536	·555	40·47	·34	37·93
16	17·225	353·610	54	·527	·460	40·72	·34	38·17
18	17 244	353·664	40	·519	·352	40·97	·33	38·40
20	17·258	353·704	27	·511	·230	41·22	·33	38·63
22	17·268	353·731	14	+0·503	−10·095	41·47	0·32	38·87
24	17·273	353·745	2	·496	9·947	41·72	·31	39·10
26	17·274	353·747	12	·489	9·787	41·97	·31	39·34
28	17·271	353·735	25	·483	9·613	42·22	·30	39·57
30	17·263	353·710	38	·477	9·426	42·46	·29	39·80
Dec. 2	17·251	353·672	52	+0·471	−9·226	42·71	0·28	40·03
4	17·235	353·620	64	·466	9·013	42·95	·27	40·25
	17·215	353·556	77	·461	8 787	43·19	·25	40·48
8	17·190	353 479	91	·457	8·548	43·42	·24	40·70
	17·160	353·388	103	·453	8·296	43·65	·23	40·91
12	17·127	353·285	115	+0·449	−8 031	43·88	0·22	41·12
14	17·089	353·170	128	·446	7·754	44·10	·20	41·33
16	17·047	353·042	140	·444	7·465	44·31	·19	41·53
18	17·001	352·902	152	·442	7·163	44·52	·17	41·73
20	16·950	352·750	163	·440	6·850	44·72	·16	41·92
22	16·896	352·587	174	+0·439	−6·526	44·91	0·15	42·10
24	16·838	352·413	184	·438	6·191	45·10	·13	42·27
26	16 776	352·229	194	·438	5·845	45·28	·12	42·44
28	16·711	352·035	204	·438	5·490	45·45	·10	42·60
30	16·642	351·831	213	·438	5·125	45·60	·09	42·74
1896.								
Jan. 1	16·570	351·618		+0·439	−4·751	45·75	0·08	42·88

Greenwich Noon.	Brightness in Sstar Magn.	Longitude of ☿'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O	B
1895.	m	°	°	°	m	°	°
Nov. 4	−1·78	59·91	144·47	·51	42·438	342·1783	·9379
6	−1·79	15·73	85·04	·51	42·179	342·3407	·9296
8	−1·81	331·57	25·62	·50	41·922	342·5030	·9213
10	−1·82	287·43	326·21	·50	41·665	342·6653	·9130
12	−1·83	243·29	266·81	+0·49	41·410	342·8276	+0·9047
14	−1·84	199·17	207·42	·49	41·156	342·9898	·8964
16	−1·86	155·05	148·05	·48	40·905	343·1520	·8881
18	−1·87	110·95	88·69	·47	40 656	343·3141	·8798
20	−1·88	66·86	29·34	·46	40·409	343·4761	·8715
22	−1·90	22·78	330·00	+0·44	40·165	343·6381	+0·8631
24	−1·91	338·71	270·67	·43	39·925	343·8001	·8548
26	−1·92	294·66	211·35	·42	39·688	343·9620	·8465
28	−1·94	250·61	152 04	·40	39·455	344·1239	·8382
30	−1·95	206·58	92·74	·39	39·226	344·2857	·8298
Dec. 2	−1·96	162·55	33·46	+0·37	39·002	344·4475	+0·8214
4	−1·97	118·54	334·18	·35	38·783	344·6093	·8131
6	−1·99	74·53	274·91	·34	38·569	344·7710	·8047
8	−2·00	30·53	215·66	·32	38·361	344·9327	·7963
10	−2·01	346·55	156·41	·30	38·158	345·0943	·7879
12	−2·02	302·57	97·17	+0·28	37·962	345·2559	+0·7795
14	−2·03	258·60	37·94	·26	37·772	345·4174	·7711
16	−2·04	214·64	338·72	·24	37·589	345·5789	·7627
18	−2·05	170·69	279·51	·22	37·413	345·7404	·7543
20	−2·06	126·74	220·30	·20	37·244	345·9018	·7459
22	−2·07	82·80	161·10	+0·18	37·083	346·0632	+0·7375
24	−2·08	38·87	101·91	·17	36·931	346·2245	·7291
26	−2·09	354·94	42·72	·15	36·787	346·3858	·7207
28	−2·10	311·02	343·54	·13	36·651	346·5470	·7123
30	−2·11	267·10	284·36	·11	36·524	346·7082	·7039
1896							
Jan. 1	−2·11	223·19	225·18	+0·10	36·407	346·8694	+0·6954

The angle L—O+180° is the jovicentric longitude of the Earth, reckoned in the assumed plane of *Jupiter's* equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere, or the point of the descending node of the planet's equator on its orbit. B denotes the jovicentric latitude of the Earth above *Jupiter's* equator, Λ—L the difference between the longitudes of the Sun and of the Earth.

The apparent diameters of the disc of *Jupiter* depend on Barnard's measurements, published in No. 325 of *Gould's Astron. Journal*, allowance being made for the Earth's latitude above the plane of *Jupiter's* equator. If cos ϵ_0 denotes the ratio of the polar axis of the planet's spheroid to its equatorial diameter, and cos ϵ the ratio of the apparent diameters of the disc as seen from a distant point in latitude B, the connection between cos ϵ and cos ϵ_0 is found from the equation sin ϵ=sin ϵ_0 cos B.

Hence

$$\cos\epsilon = \cos\epsilon_0\sqrt{1+\tan^2\epsilon_0\sin^2 B}$$
$$= \cos\epsilon_0 \,.\, \sec\nu, \text{ if } \tan\nu = \tan\epsilon_0 \sin B.$$
$$\cos\epsilon_0 = \cos\epsilon\sqrt{1-\tan^2\epsilon\tan^2 B}$$
$$= \cos\epsilon \,.\, \cos\gamma, \text{ if } \sin\gamma = \tan\epsilon\tan B.$$

The formulæ for finding the differences of tangents to the limbs in right ascension and declination and the defects of illumination are given in vol. xlv., p. 508.

The longitudes of *Jupiter's* central meridian are computed with the values of the rates of rotation and of the zero meridians adopted in the preceding ephemerides. The addition of the "Corr. for Phase" gives the longitudes of the meridian which bisects the illuminated disc. The following is a list of Greenwich mean times when the adopted zero meridians in the assumed two systems of longitudes will pass the middle of the illuminated disc :—

	I. (877° 90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1895.	h m	h m	1895.	h m	h m
Aug. 30	17 24·0	21 11·3	Sept. 10	19 9·9	15 21·2
31	22 55·8	17 2·8	11	14 51·0	21 8·5
Sept. 1	18 37·0	22 50·1	12	20 22·8	17 0·0
2	14 18·1	18 41·7	13	16 3·9	22 47·3
3	19 49·9	14 33·2	14	21 35·6	18 38·8
4	15 31·1	20 20·5	15	17 16·8	14 30·3
5	21 2·9	16 12·1	16	22 48·5	20 17·6
6	16 44·0	21 59·4	17	18 29·6	16 9·1
7	22 15·8	17 50·9	18	14 10·8	21 56·3
8	17 57·0	23 38·2	19	19 42·5	17 47·8
9	23 28·7	19 29·7	20	15 23·6	23 35·0

1895.	I. (877°·90) h m	II. (870°·27) h m	1895.	I. (877°·90) h m	II. (870°·27) h m
Sept. 21	20 55·3	19 26·5	Oct. 21	9 34·2	14 18·3
22	16 36·4	15 18·0		19 24·8	24 14·0
23	22 8·1	21 5·2	22	15 5·8	10 9·7
24	17 49·2	16 56·7		24 56·3	20 5·3
25	13 30·6	12 48·2	23	10 46·8	15 56·7
	23 20·9	22 43·9		20 37·3	25 52·4
26	19 2·0	18 35·4	24	16 18·3	11 48·1
27	14 43·1	14 26·9	25	11 59·4	17 35·2
28	0 33·7	0 22·6	26	17 30·9	13 26·5
	20 14·8	20 14·0	27	13 11·9	9 17·9
29	15 55·9	16 5·5		23 2·4	19 13·5
30	21 27·6	21 52·7	28	18 43·4	15 5·0
Oct. 1	17 8·7	17 44·1	29	14 24·4	10 56·3
2	12 49·8	13 35 6		24 14·9	20 52·0
	22 40·3	23 31·3	30	19 55·9	16 43·4
3	18 21·4	19 22·8	31	15 36·9	12 34·7
4	14 2·5	15 14·2	Nov. 1	11 17·9	8 26·1
5	19 34·1	21 1·4		21 8·4	18 21·8
6	15 15·2	16 52·8	2	16 49·4	14 13·1
7	10 56·3	12 44·3	3	12 30·4	10 4·4
	20 46 8	22 40·0		22 20·9	20 0·1
8	16 27 9	18 31·4	4	8 11·4	15 51·4
9	12 9·0	14 22·8		18 1·9	25 47·1
	21 59·5	24 18 6	5	13 42·9	11 42·8
10	17 40·6	20 10·0		23 33·4	21 38·4
11	13 21·6	16 1·4	6	9 23·9	7 34·1
	23 12·2	25 57·1		19 14·3	17 29·8
12	18 53·2	21 48·5	7	14 55·3	13 21·1
13	14 34·3	17 40·0		24 45 8	23 16·8
14	10 15·4	13 31·4	8	10 36·3	9 12·4
	20 5 9	23 27·1		20 26·8	19 8·1
15	15 46·9	19 18·5	9	16 7·7	14 59·4
16	21 18·5	15 9·9	10	1 58 2	0 55·1
17	16 59 6	20 57·0		11 48·7	10 50·7
18	12 40·6	16 48·4		21 39 2	20 46·4
19	18 12·2	12 39·8	11	17 20·1	16 37·7
20	13 53·2	8 31·2	12	13 1·1	12 29·0
	23 43 7	18 26 9		22 51·6	22 24·7

1895.	I. (877°·90) h m	II. (870°·27) h m
Nov. 13	8 42·0	8 20·3
	18 32·5	18 16·0
14	14 13·5	14 7·3
15	0 3·9	0 2·9
	9 54·4	9 58·6
	19 44·9	19 54·2
16	15 25·8	15 45·5
17	11 6·8	11 36·8
	20 57·2	21 32·5
18	16 38·2	17 23·8
19	12 19·1	13 15·1
	22 9·6	23 10·7
20	8 0·1	9 6·3
	17 50·5	19 2·0
21	13 31·5	14 53·3
	23 21·9	24 48·9
22	9 12·4	10 44·5
	19 2·8	20 40·2
23	0 20	Sat. IV. Shadow crossing central Meridian.
	14 43·8	16 31·5
24	10 24·7	12 22·7
	20 15·1	22 18·4
25	15 56·0	18 9·6
26	11 36·9	14 0·9
	21 27·4	23 56·5
27	7 17·8	9 52·1
	17 8·3	19 47·8
28	12 49·2	15 39·0
29	8 30·1	11 30·3
	18 20·5	21 25·9
30	14 1·5	17 17·2
Dec. 1	9 42·3	13 8·4
	19 32·8	23 4·0
2	5 23·4	8 59·7
	15 13·7	18 55·3
3	10 54·6	14 46·5
	20 45·0	24 42·1

1895.	I. (877°·90) h m	II. (870°·27) h m
Dec. 4	6 35·4	10 37·8
	16 25·9	20 33·4
5	12 6 8	6 29·0
	21 57 2	16 24·6
6	7 47·6	12 15·8
	12 16	Sat. III. Sh.
	17 38·1	22 11·4
7	13 19·0	8 7·0
	23 4·4	18 2·7
8	8 59 8	13 53·9
	18 50·3	23 49·5
9	14 31·1	9 45·1
	18 19	Sat. IV. Sh.
	24 21·6	19 40·7
10	10 12·0	5 36·3
	20 2·4	15 31·9
11	5 52·9	11 23·2
	15 43·3	21 18·8
12	11 24·2	7 14·4
	21 14·6	17 10·0
13	7 5·0	13 1·2
	16 14	Sat. III. Sh.
	16 55·4	22 56·8
14	12 36·3	8 52·4
	22 26·7	18 48·0
15	8 17·2	14 39·2
	18 7·6	24 34·8
16	13 48·4	10 30·4
	23 38·9	20 26·0
17	9 29·3	6 21·6
	19 19·7	16 17·2
18	5 10·1	12 8·4
	15 0·6	22 4·0
19	10 41·4	7 59·6
	20 31·8	17 55·2
20	16 12·7	13 46·4
	20 14	Sat. III. Sh.
21	11 53·5	9 37·6

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1895	h m	h m	1895	h m	h m
Dec. 21	21 43·9	19 33 2	Dec. 26	19 48·9	18 40·2
22	7 34·3	5 28·8	27	15 29·7	14 31·4
	17 24·7	15 24·3	28	11 10·5	10 22·6
23	13 5·6	11 15·5		21 0·9	20 18·2
	22 56·0	21 11·1	29	6 51·3	6 13·8
24	8 46·4	7 6·1		16 41·7	16 9·4
	18 36·8	17 2·3	30	12 22·6	12 0·5
25	14 17·6	12 53·5		22 13·0	21 56·1
26	9 58·5	8 44·7	31	8 3·4	7 51·7
	12 18	Sat. IV. Sh.		17 53·8	17 47·3

(*To be continued in the Supplementary Number.*)

Colonel Cooper's Observatory,
Markree, Collooney, Ireland.

Correction.

Mr. Barnard's attention has been called by Mr. T. J. Moore, of Doncaster, England, to an error in the value given in Mr. Barnard's paper on *Saturn*, *Monthly Notices*, vol. lv. p. 377.

For the polar compression

$$C = \frac{E-P}{E}$$

should be $\frac{1}{12\,35}$

instead of $\frac{1}{11{\cdot}44}$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. SUPPLEMENTARY NUMBER. No. 9

On the Accuracy of Late Catalogues of Declination of Standard Stars. By Professor Truman Henry Safford.

If we desire to make observations with meridian instruments which shall be as accurate and independent as possible we can either refer the declinations to the zenith by direct observation of the nadir point, or by stars taken directly and by reflection, or by horizontal levelled collimators; or we can employ an instrument which turns around a vertical axis, and use it in opposite positions. In either case we shall need to determine the latitude systematically by observations above and below pole.

If this course is pursued it is best to determine the refraction coefficient also by observing stars below pole and comparatively near the horizon. With two nearly identical instruments the refraction coefficient can also be controlled by observations in the opposite hemisphere. But a great multitude of observations have been differentially interpolated in declination, as well as in right ascension, between stars absolutely determined elsewhere or at other times. At present the catalogue most used as a standard one is that of the Berlin *Jahrbuch* as compiled by Professor Auwers. The probable error of a position of this catalogue is small, although at present larger than is altogether desirable. This has led its compiler to base the zone observations now going on south of the celestial equator upon an independent determination of zero stars at the Cape of Good Hope and other favourably situated observatories; and the revision of the *Jahrbuch* list itself is now in progress.

The investigation which here follows was made in order to answer some questions which came up in a paper I am now preparing—a final revision of the declinations of 627 stars compiled for the Mexican Boundary Commission. So many new star catalogues have been published since that list was prepared in 1892 and 1893 that the probable errors of the declinations contained in it would in many cases be sensibly lessened by including them; and these probable errors, though small enough for the practical needs of the Commission, were for some stars quite sensibly too large for convenience in the further use of the catalogue for other purposes.

The first step taken was to compare the Berlin *Jahrbuch* Catalogue with the Greenwich Ten-year and Five-year combined; with Nyrén's Pulkova declinations for 1885; with the Cape Catalogue of the same epoch; and with the Radcliffe Catalogue for 1890. The Greenwich combination includes all observations of fundamental declinations from 1877 to 1891; the Radcliffe Catalogue contains observations from 1880 to 1893 inclusive. The four modern catalogues are all dependent upon work of so nearly the same mean epoch that uncertainty of proper motion will have little effect on the comparisons, and they all cover so many 427 day periods that one principal term in the variation of latitude nearly disappears in the mean. The whole variation of latitude is eliminated from the Pulkova series by direct observations in sufficient number. This excellent catalogue is based upon double observations with a vertical circle, practically an altazimuth with a horizontal circle used only for setting. Most stars are observed with it twice in opposite positions of the face of the divided circle at the same culmination; *Polaris* is observed four times at each culmination; but stars within five degrees of the zenith are only once observed. In this case the zenith distance changes too rapidly while the observation is going on. The probable error of an ordinary (double) observation is lessened very much by the immediate reversal, and consequent elimination, of index error; but for the zenith stars this favourable circumstance disappears.

The normal number of double observations is eight for each star of the Pulkova Hauptsterne. Stars near the zenith are taken singly sixteen times; but as their zenith distance below pole is about 65° at most, they are more accurately determined by sixteen single observations above pole, and eight double ones below, than the stars further south, although not quite as precisely as those further north which have eight double observations in each position.

In his paper on the variation of latitude as derived from this series, Mr. Nyrén gives the following weights for a single declination, depending on four bisections for *Polaris* (E.W.W.E. or W.E.E.W.), two for most stars E.W. or W.E., and one for zenith stars:—

	Weight.*	Probable Error.
Single observations within 4° of the zenith ...	1·16	±0″·38
Double observations from Z.D. 4°–50° ...	3·47	±0·22
„ „ „ 50°–65° Z.D. ...	2·31	±0·27
„ „ „ 65°–76° Z.D. ...	1·0	±0·41
Quadruple observations of Polaris	6·38	±0·16

From these probable errors and the minimum number of observations for each declination we find the probable error of the resulting mean declinations, so far as it arises from the agreement, *inter se*, of the separate observations to vary between ±0″·055 and ±0″·13 between the declinations 90° and −16°. The largest value applies to few stars, and the general average is ±0″·08. These values should be diminished for stars more frequently observed than the rule requires.

The Greenwich results for 1877 to 1891 inclusive are liable to a probable error for the single observation (according to Mr. Stone's investigation quoted in the Introduction to the Greenwich Observations) varying from ±0″·47 at the zenith to ±0″·60 at a zenith distance of 45° and ±0″·95 at 75°. The harmonic mean of the number of observations is forty-one; and taking ±0″·55 as the average probable error of the single one, we find ±0″·09 as that part of the probable error of the mean result for fifteen years which arises from the accidental causes which are exhibited in Mr. Stone's calculations.

As is at once visible from Mr. Thackeray's tables in the *Monthly Notices* for November 1894, the combination of the two quantities ±0″·08 and ±0″·09 does not give a large enough probable error of result; as was indeed to be expected. We do not know how the subdivisions of the degrees in Repsold's dividing engine or in the Greenwich Transit Circle were made. We shall presently see that each instrument and method of observing is apparently responsible for a residual probable error of ±0″·09, or slightly more, in the result of a large number of observations. And this estimate is for Greenwich decidedly less than the quantity ±0″·16 allowed in the Greenwich Introduction. It must, of course, be remembered that this last quantity is to be diminished before application to the final catalogue positions in consequence of the employment of many observations by reflection, and perhaps of the combination of observations above and below pole. The refraction employed was, however, not determined by bringing observations above and below pole to agree, but was Bessel's.

The Pulkova observations were reduced by a refraction coefficient derived from themselves in the manner just indicated. The number of observations below and above was very carefully regulated. The errors of division were determined for each degree,

* *Mélanges Mathématiques et Astronomiques*, vol. vii., p. 356.

and the division lines had been put on anew by the Repsolds. The residual probable error of the division lines (as at Greenwich) is probably a sensible portion of the remaining probable error of results; and such a residual error is to be determined by the combination of independent series. In these observations the variation of latitude was allowed for by direct determination.

In comparing among themselves the three catalogues, Berlin *Jahrbuch*, 1885, Nyrén 1885, and Greenwich 1877–1891, I divided them into zones of declination, and did not consider the variation in the different hours of right ascension. There were indications that this variation contained terms constant for different declinations; but on the one hand these terms were small, on the other there was no means of separating them from others of equal importance, which varied both in right ascension and declination. It seemed safe enough to allow for the variations with respect to declination directly, and leave the remainder to be included with the probable errors, which are, of course, made a little too large by them. The variations which are functions of the declination alone arise from definite causes; refraction and flexure, whose laws do not seem to be accurately known to the last degree of precision; while those variations which are functions either of the right ascension alone or of right ascension and declination conjointly include undetermined remainders from many causes, including variation of latitude. The attempt to separate the last cause from the others proved fruitless. The coefficients of the sine and cosine of the right ascension in the difference between the Berlin *Jahrbuch* and Pulkova 1885 came out so small, as compared with those of the sine and cosine of double the right ascension, that a correction formula to the *Jahrbuch* declinations, suggested by Dr. Chandler as arising from the annual term in the variation of latitude, was apparently neutralised by other causes. The course, then, of including variations depending upon right ascension in the casual errors seemed allowable so long as they were sufficiently small and irregular.

The method of dealing with the differences of two catalogues used was simply to group them in declination, and to compare each difference with the mean of its group, without smoothing them off at the boundaries of the groups by the aid of curves. In this way the casual errors are also somewhat increased by the irregularities at the boundaries. In spite of this, however, the resulting probable errors were found unexpectedly small, as will be seen when they are compared with those derived from the earlier Greenwich catalogues and the Pulkova declinations for 1865. The first group included the stars common to the *Jahrbuch* and Pulkova 1885 between 90° and 60°. It had been found by trial that a group of this extent could safely be here taken.

There were forty-nine stars; the mean $\Delta\delta$ was $-0''{\cdot}08$; the

probable error of one difference by *sums* of differences was $\pm 0''\cdot196$.

This and the remaining groups in the same comparison gave the following table :—

Berlin Jahrbuch – Pulkova 1885.

Limits of Zone.		No. of Stars.	Mean $\Delta\delta$.	P.E. 1 Diff.*	$\Sigma\epsilon$.
°	°		″	″	″
90	60	49	−0·08	±0·196	11·25
60	50	29	+0·01	0·216	7·28
50	40	39	−0·05	0·185	8·43
40	30	43	+0·28	0·194	9·76
30	20	46	+0·21	0·185	9·98
20	10	46	+0·23	0·174	9·23
10	0	46	+0·23	0·173	9·31
0	−10	41	+0·13	0·235	11·25
−10	−20	34	−0·31	0·267	10·57
−20	−27	7	−0·46	0·45	3·43

The original catalogue of the Berlin *Jahrbuch* and the earlier catalogue of Pulkova Hauptsterne end at −10°, and the more southerly stars were introduced into the latter partly for determination of refraction. The differences between the two series south of that limit arise in part from the two independent refraction coefficients used at Pulkova 1865 and Pulkova 1885, combined with the employment of the inside thermometer to modify the readings of the outer one.

The stars of the *Jahrbuch* south of −10° were computed (Publication xvii. of the *Astro. Gesellschaft*) from a number of other catalogues not used in the portion taken from Publication xiv. Hence the probable errors of our difference are not quite comparable in the two cases. North of −10° we have 339 stars, in eight groups, with $\Sigma\epsilon$ 76″·49 ; the average probable error of one difference is $\pm 0''\cdot193$. The addition of the thirty-four stars from −10° to −20° would make this value $\pm 0''\cdot200$; the remaining seven are at Pulkova below Z.D. 80°.

The next comparisons made were those between the two separate catalogues and Greenwich 1880–90; that is, the Ten- and Five-year Catalogues, combined in proportion to the number of observations : this combination I shall call Greenwich 1885 (1877·0—1892·0) ; the first group extended to 50° north declination, practically the zenith of Greenwich. The resulting table is as follows :—

* The probable errors are determined from the sums of the errors, regardless of sign, both here and in what follows.

Berlin Jahrbuch – Greenwich 1885.

Limits of Zone.	No. of Stars.	Mean $\Delta\delta$.	P.E. 1 Diff.	$\Sigma\epsilon$.
° °		″	″	″
90 −50	22	−0·06	±0·228	5·80
50 −40	8	−0·01	0·219	1·94
40 −30	11	+0·12	0·164	2·04
30 −20	19	+0·16	0·155	3·39
20 −10	27	+0·15	0·154	4·82
10 0	29	+0·17	0·207	6·97
0 −10	24	−0·03	0·192	5·33
−10 −20	18	−0·02	0·186	3·86

The probable error, ±0″·228 in the zone 90° to 50°, is somewhat larger than that in the average of the zones south of the zenith of Greenwich, which comes out ±0″·181. The reason for this difference, which seems to be real, is not a less number of observations to each star of the 22, as they are all well-known fundamentals * observed rather oftener than the average.

The comparison Greenwich 1885–Pulkova 1885 gives the following results :—

Limits of Zone.	No. of Stars.	Mean $\Delta\delta$.	P.E. 1 Diff.	$\Sigma\epsilon$.
° °		″	″	″
90 −50	22	+0·01	±0·201	5·11
50 −40	8	−0·09	0·249	2·20
40 −30	11	+0·20	0·157	1·95
30 20	21	+0·10	0·116	2·83
20 10	28	+0·04	0·153	4·98
10 0	29	+0·05	0·185	6·23
0 −10	25	+0·04	0·207	6·11
−10 −20	18	−0·36	0·181	3·75
−20 −27	6	−0·29	0·33	2·13

We now combine the probable errors of the separate groups. Below 10° of south declination the *Jahrbuch* positions are not of approximately uniform accuracy ; and the least accurate of them are those not in the Greenwich standard list.

We can then properly divide the stars into three groups :—

A. Those between the pole and the zenith of Greenwich.

B. Those between the zenith of Greenwich and −10° of declination.

C. Those south of the last-mentioned parallel to −20° (or 80° Z.D. at Pulkova).

* I added three : *Cephei* 43 H., Groombridge 750, and *Draconis* 1 H., which Mr. Thackeray seems to have overlooked.

The probable errors in the mean are as follows :—

	B.J.-Pulk. 1885.	B.J.-G. 1885.	G. 1885-P. 1885.
Group A.	±0".204 78 stars	±0".228 22 stars	±0".201 22 stars
Group B.	±0".190 261 „	±0".180 118 „	±0".172 122 „
Group C.	±0".267 34 „	±0".186 18 „	±0".181 18 „
General Mean	±0".200 344 „	±0".187 158 „	±0".176 162 „

The results from the general mean when properly combined indicate the probable error of Greenwich 1885, ±0".114; of Pulkova 1885 ±0".134; of the *Jahrbuch* declination for 1885 ±0".148.

Professor Auwers has investigated the mean errors for the *Jahrbuch* positions by the agreement *inter se* of the materials employed.

From his data, vol. cxxxiv. col. 18 of the *Astronomische Nachrichten*, combined with the relative number of stars in the different classes, we find the average *mean* error for 1885·0 of a Hauptstern (in declination) to be ±0".222, and of a Zusatzstern, ±0".24. As Nyrén's stars are mostly Hauptsterne, with a few lately transferred from the other list, we can fairly take ±0".15 as the probable error in question, agreeing very closely with the value ±0".148. The former quantity is derived from the comparison *inter se* of the materials for the *Jahrbuch* declination, together with an estimate for the proper motions since the average epoch derived from Bradley.

We may safely conclude, then, that the probable error, B.J.—Pulkova ±0".193 for 1885 is nearly correct. I have here omitted the last group as less accurate in both catalogues owing to the fact that the zenith distances exceed 70°.

The half of this amount, ±0".096, can be taken as the probable error of the half sum of the declinations from the two catalogues as reduced to 1885, and including the more southerly declinations we can employ ±0".100 as a general mean.

I now attempted a little additional test of the Greenwich declinations between the north pole and the zenith. The table of differences showed that the probable errors of the Greenwich declinations in this region were larger than elsewhere; and a plausible cause for this seemed to be the use of Bessel's refractions unchanged. The indication from several sources is that these should be slightly diminished, not by so much as was done in constructing the Nine-year Catalogue, but by a large fraction of this amount. The Greenwich declinations above and below pole are, as it seems, systematically different by a slight amount owing to this cause. Professor Auwers finds it necessary to add larger (positive) systematic corrections to the declinations below pole than to those taken above; the difference for the stars which at upper culmination pass through the zenith is about 0".8; and the correction to the refraction coefficient is about −0".15, which

corresponds pretty nearly to the results of Dr. Gill's investigations, and to the Pulkova tables of Gyldén.

We compare, then, the combined Greenwich declinations, 1885, with those obtained by taking the half sum of Nyrén's results for that date and those of the *Jahrbuch*. The mean of differences for the twenty-two stars north of 50° is −0″·03 : the sum of remaining errors without regard to sign is 5″·14, and the probable error of a difference is ±0″·202. As the probable error of $\frac{\text{B.J.}+\text{Nyrén}}{2}$ is ±0″·102 in this region, we have the p.e. of one Greenwich result

$$= \sqrt{0{\cdot}304 \times 0{\cdot}100} = \pm 0''{\cdot}174.$$

In order to make sure of this point I examined the comparisons between results above and below pole, as given in the Introductions to the Ten- and Five-year Catalogues respectively. The number (22) of Greenwich fundamental stars between the pole and zenith seemed to me too small to furnish a base for an important conclusion. I then brought together the results given in the Introduction to the Ten-year and Twelve-year Catalogues for stars which had been observed twenty or more times each in either catalogue.

For the Ten-year Catalogue twenty-four stars within 15° of the pole gave the sum of errors 9″·16, and probable error ±0″·323 for one difference. But there was a constant difference in this region of −0″·15. Allowing for this the sum of errors became 8″·46, and the probable error ±0″·304 ; the harmonic mean of the number of observations was twenty-eight. In the Five-year Catalogue were found sixteen stars meeting the same condition. The sum of errors, without regard to sign, was 6″·15, and the probable error ±0″·325, but the constant difference was more marked. All but two of the differences were negative ; the mean difference *with* regard to sign was −0″·30, and after it was allowed the sum of errors, without regard to sign, was 3″·91, and the probable difference ±0″·213 for a harmonic mean of sixty-one observations.

The existence of the constant difference is plainly enough shown by the four principal polars.

	Ten-year. No. Obs.	Below−Above.*	No. Obs.	Five-year. Below−Above.*	
		″		″	* In declination; Above−Below in N.P.D.
Polaris	1433	−0·36	626	−0·46	
51 H. Cephei	595	−0·78	265	−0·48	
8 Ursæ Minoris	589	−0·69	232	−0·49	
λ Ursæ Minoris	489	−0·74	227	−0·49	
Mean ...	...	−0·64	...	−0·42	

The same phenomenon is pretty clearly visible on page 13 of the Five-year Catalogue, and less consistently on page 46 of the Ten-year.

It will probably be safe to follow the indications of the comparisons with Pulkova and the *Jahrbuch*.

So far as probable error is concerned I shall divide the stars between 90° and −10° at the zenith of Greenwich. We have then for group A, denoting by ϵ_1 the probable error of a declination in the *Jahrbuch* for 1885, by ϵ_2 of one in Pulkova 1885, and by ϵ_3 of one in Greenwich (1885) :—

$$\epsilon_1^2+\epsilon_2^2=(0''.204)^2 \qquad \epsilon_1=\pm 0''.163$$
$$\epsilon_1^2+\epsilon_3^2=(0''.228)^2 \qquad \epsilon_2=\pm 0''.123$$
$$\epsilon_2^2+\epsilon_3^2=(0''.201)^2 \qquad \epsilon_3=\pm 0''.159$$

For group B

$$\epsilon_1^2+\epsilon_2^2=(0''.190)^2 \qquad \epsilon_1=\pm 0''.139$$
$$\epsilon_1^2+\epsilon_3^2=(0''.180)^2 \qquad \epsilon_2=\pm 0''.129$$
$$\epsilon_2^2+\epsilon_3^2=(0''.172)^2 \qquad \epsilon_3=\pm 0''.114$$

The results from group C are abnormal, as was perhaps to be expected. The eighteen stars in it in the Greenwich Fundamental Catalogues have a larger weight in the *Jahrbuch* than the remainder of those common to the *Jahrbuch* and Pulkova, and the square of ϵ_3, the probable error for Greenwich, comes out negative. The combination of B and C gives the following results :—

$$\epsilon_1^2+\epsilon_2^2=(0''.199)^2 \qquad \epsilon_1=\pm 0''.146$$
$$\epsilon_1^2+\epsilon_3^2=(0''.181)^2 \qquad \epsilon_2=\pm 0''.136$$
$$\epsilon_2^2+\epsilon_3^2=(0''.173)^2 \qquad \epsilon_3=\pm 0''.107$$

In order to gain a clearer idea of the increase in probable error in the Pulkova series near the south horizon I compared the Berlin *Jahrbuch* for 1885 and Nyrén 1885 with Professor Auwers's catalogue of 303 stars in *A.N.*, Nos. 2890–91, vol. cxxi. Below −15° I did not attempt the triple comparison. But from +6° the northern limit of the 303 stars to −15° I found the following equations, in which ϵ_4 denotes the probable error of a declination from the 303 stars :—

$$\epsilon_1^2+\epsilon_2^2=(0''.220)^2 \qquad \epsilon_1=\pm 0''.160$$
$$\epsilon_1^2+\epsilon_4^2=(0''.199)^2 \qquad \epsilon_2=\pm 0''.150$$
$$\epsilon_2^2+\epsilon_4^2=(0''.191)^2 \qquad \epsilon_4=\pm 0''.118$$

The catalogue of 303 stars is obtained by a combination of observations at the Cape of Good Hope, Madison, Annapolis, and Cordoba ; for some cases (none of which are included in these

comparisons) a few other observations are added. The Cape results combined with the Cordoba Catalogue would lead us to expect a probable error of rather less than $\pm 0''.16$; so that if the weight of the Madison and Annapolis observations is about equal to that of the Cape and Cordoba the probable error of all would be approximately $\pm 0''.11$, and the mean epoch very little different from 1885.

The value of $\epsilon_1^2+\epsilon_2^2=(0''.220)^2$ is larger than was found for group B as a whole by the previous comparisons, but not more than the average declination would lead us to expect. In order to extend the value still farther south I compared Nyrén (Pulkova 1885) with ½ (B.J.+303) and found in the mean

$$\epsilon_2(+6^\circ \text{ to } -15^\circ) = \pm 0''.158$$
$$\epsilon_2(-15 \text{ to } -26) = \pm 0''.265$$

considering the probable error of ½ (B.J.+303) $\pm 0''.100$ to apply to the southern limit of the Pulkova list.

The next set of comparisons made were those of the declinations of the Cape Catalogue for 1885 with the half sum of B.J.+Nyrén. The results were divided into two groups, according as the number of observations at the Cape was ten or more, or less than ten. No comparison was made north of $+40^\circ$ or south of -20°. The groups are from 10° to 10°, and the harmonic mean number of observations is given for each group.

Comparison of Cape Catalogue with ½ (B.J.+Nyrén).

Declination.	Harmonic Mean No. Obs.	Mean Δδ.	No. Stars.	P.E. 1 Diff.	Harmonic Mean No. Obs.	Mean Δδ.	No. Stars.	P.E. 1 Diff.
$+40^\circ$ to $+30^\circ$	15·5	$-0''.04$	13	$\pm 0''.257$	2·8	$-0''.10$	17	$\pm 0''.556$
$+30$ to $+20$	15·5	$+0''.06$	14	$\pm 0''.273$	3·8	$-0''.01$	26	$\pm 0''.329$
$+20$ to $+10$	16·7	$+0''.11$	24	$\pm 0''.290$	2·5	$-0''.08$	20	$\pm 0''.319$
$+10$ to 0	23·8	$+0''.24$	42	$\pm 0''.157$	4·2	$+0''.44$	4	$\pm 0''.290$
0 to -10	20·5	$+0''.25$	41	$\pm 0''.138$	...	...	...	...
-10 to -20	19·6	$+0''.28$	33	$\pm 0''.198$	...	...	...	...
General Mean	19·4	...	167	$\pm 0''.197$	3·1	...	67	$\pm 0''.385$

The probable error of ½ (B.J.+Nyrén) being taken as $\pm 0''.100$ we have

P.E. Cape	19·4	observations	$\pm 0''.170$
	3·1	„	$\pm 0''.372$

Between $+10^\circ$ and -20° we find the probable error of about twenty Cape observations to be

$$\sqrt{(0''.184)^2-(0''.100)^2} = \sqrt{0''.284 \times 0''.084} = \pm 0''.154.$$

A similar comparison was made with the Radcliffe Catalogue for 1890. As this depends upon the observations from 1880 to 1893 inclusive its mean epoch is not essentially different from that of the other catalogues compared.

The stars were grouped as for the Cape Catalogue, namely, those observed more than ten or more times in a group (α) and those observed less than ten times in a group (β). As the separate groups often contained few stars, I took the mean $\Delta\delta$ for each zone, giving half-weight to a star in group (β) and weight-unity to one in group (α).

Limits of Zone.		Mean $\Delta\delta$.	Probable Diff. 1 Star (α).	No. Stars (α).	Probable Diff. 1 Star (β).	No. Stars (β).
°	°	″	″		″	
90	−80	−0·02	±0·184	5	...	(1)
80	70	−0·06	0·105	9	±0·211	9
70	60	−0·47	0·162	12	0·373	6
60	50	−0·61	...	(1)	0·343	14
50	40	−0·42	0·217	3	0·361	16
40	30	−0·57	0·244	11	0·258	14
30	20	−0·86	0·208	13	0·266	16
20	10	−0·92	0·199	16	0·267	25
10	0	−0·90	0·210	5	0·308	26
0	−10	−0·78	0·210	13	0·385	30
−10	−20	−0·62	0·233	12	0·336	21
−20	−30	−1·23	0·27	4	0·38	2
General Mean		...	±0·201	103	±0·316	179

Allowing ±0″·100 for the probable error of $\frac{\text{B.J.}+\text{Nyrén}}{2}$ we find

P.E. 1 declination R.C., 10 observations or more ±0″·174
less than 10 observations ±0·300

For the first division the harmonic mean of the number of observations is 15·1 ; for the second, 4·3.

In order to get an estimate of the probable error of the Greenwich declinations for a less number of observations I had already compared 200 stars from my Mexican Boundary calculations. The probable error for two, three, or four observations was found ±0″·346. This applies to the Ten-year Catalogue and to the stars since observed, of which I had collected the observations from the annual volumes of results ; and the quantity found is very nearly equal to Professor Auwers's result for his weight unity for the Nine-year Catalogue. As an intermediate step I compared the mean of B.J. and Nyrén with the Five-year or Ten-year, so far as the latter's numbers are given

in the Five-year, taking as the Greenwich declination to be used the one of the two in which the observations are less in number. This gave me for a harmonic mean of nine observations $\pm 0''.193$ as the probable error of a Greenwich declination.

We can now place side by side the probable errors of the results of the three English instruments.

	G.		C.		R.
3	$\pm 0''.346$	3·1	$\pm 0''.372$	4·3	$\pm 0''.300$
9	$\pm 0''.193$	19·4	$\pm 0''.170$	15·1	$\pm 0''.174$
41	$\pm 0''.114$	...	...	...	...

The accidental error of a single observation at either place at not too great a zenith distance is not very far from $\pm 0''.50$ on the average. By a simple calculation it will be seen that the probable errors in the little table include some additional source of uncertainty, which is common to all the observations of the same star at the same place. For the forty-one Greenwich observations this appears to amount to $\pm 0''.08$; for the 19·4 Cape observations to $\pm 0''.13$, for the 15·1 Radcliffe observations to $\pm 0''.12$. The Cape Catalogue is based upon only six years' observations, and the variation of latitude is perhaps less perfectly eliminated in the individual stars.

The assumption of a comparatively large constant error which cannot be diminished by repeated observation is one which is frequently made. Argelander (*Bonn Observations*, vol. vii. p. 45) assumes that such a constant error is not less than that arising from four single observations, which would give $\pm 0''.25$ in place of the quantities varying from $\pm 0''.08$ to $\pm 0''.13$, which we have just obtained. For Pulkova we find

$$\sqrt{(0''.134)^2-(0''.080)^2} = \sqrt{0''.214 \cdot 0''.054} = \pm 0''.11.$$

Professor Boss employs (in his memoir on standard declinations) for various catalogues a ratio of casual to constant error, $\frac{\epsilon}{\epsilon_1}$, equal to either 2, 3, or 4. For the two Seven-year Catalogues, and those later observations which he used, he adopts $\frac{\epsilon}{\epsilon_1}=3$, which makes the constant error for the Greenwich declinations $\pm 0''.17$; while for Mr. Main's results with the Carrington circle he takes $\frac{\epsilon}{\epsilon_1}=2$, and the constant error in any one year would be more than $\pm 0''.25$ for these observations, as the instrument was differently handled before 1880.

It is plain to be seen that the two instruments do not inevitably bring about such large constant errors. We may safely assume that after the variation of latitude has been completely eliminated the remaining discrepancies are due to three

causes rather than two. We have in the first place ordinary casual error arising from variation in bisection of the star or the divisions, or in refraction; in the third place, the unrecognised remainders of division error. Between the two we have a cause which depends upon the combination of the circumstances which enter into the observation by a given astronomer with a given instrument. This is likely to vary in its effects with the same observer from year to year, and with the same instrument used by different observers. That is to say, if the fundamental stars observed at Greenwich had been each observed forty times and no more during the years 1878 and 1891 inclusive, and if each one had been taken by ten different astronomers in groups of four observations each, there would no doubt be indications that ten different constant errors would be joined to the casual error on the one hand, and to the instrumental constant error on the other; so that the resulting probable error would be somewhat less than it is found by the previous investigation. The pure casual error would be less when the personalities are eliminated; the regularity of distribution would slightly diminish the effect of the personalities on the result.

It may be worth while to add a comparison of these with the previous results relating to the accuracy of the declinations of the best catalogues. Professor Auwers adopts the following formula for the mean error of a declination of his Bradley catalogue for a star observed n times :—

$$\epsilon = \sqrt{0''.35 + \frac{1''.36 + 0''.085 \tan^2 z}{n}}.$$

For a zenith star observed twenty-five times with the brass quadrant this would give a mean error of $\pm 0''.64$, or probable error $\pm 0''.43$; for one observed four times a mean error of $\pm 0''.83$, or probable error $\pm 0''.56$. The quantity $0''.35$, which is nearly equal to one-fourth the square of casual error of an observation, is the result of a rough estimate, and these numbers are quite as likely to be too large as too small.

Argelander's Åbo catalogue seems to be more accurate than his own estimate would make it. His own expressions for the probable casual error of a single observation are

$$0^s.0312 + 0^s.0210 \sec \delta \text{ in A.R.}$$

$$0''.859 + 0''.0644 \tan z + 0''.2577 \tan^2 z \text{ in Dec.}$$

Here z is the zenith distance.

He estimates the probable constant error arising from error of division as $\pm 0''.208$.

The formulæ are given in his paper on the solar motion, in the *Mém. des Savants Etrangers* of the Petersburg Academy of Sciences for 1837, and have been rarely noticed.

The usual number of observations for which Argelander calculates the probable error is eight, at a zenith distance of 50°.

For the fundamental and circumpolar stars, assuming the harmonic mean of the number of observations to be fifty, we should

get ±0″·25 approximately. Professor Boss' weights for eight and fifty observations are respectively 2·0 and 3·5, to which correspond probable errors of ±0″·21 and ±0″·16; the probable error of the unit of weight is ±0″·3 in his investigations. It is probable that Argelander estimates the constant error ±0″·208 on too liberal a scale, and that the zenith distance of 50° is too large for the average of the stars which are not circumpolar. If we adopt the average casual probable error of one observation as ±0″·91 we should get for its effect ±0″·35 for eight observations and ±0″·13 for fifty, leaving still unexplained differences.

The probable difference of declination between a star in the Åbo Catalogue and in Struve's *Positions Mediæ* is ±0″·39. Struve's normal number of observations is six, with a less probable error to the single observation—about ±0″·6 on the average. With the assumption of ±0″·208 for the error of division of the Åbo circle, and a similar assumption of ±0″·1 for the Dorpat instrument, we should have ±0″·28 for the probable difference Åbo-Dorpat for a fundamental star, and ±0″·44 for a non-fundamental. The ordinary assumption that the probable errors of the Dorpat and Åbo Catalogues are on the average equal is rendered plausible by the results of various comparisons made by Auwers, Seyboth, and others. Boss adopts the same weight for the two authorities, which does Struve a slight injustice, so far as his own personal observations are concerned. After he gave the circle over to his assistants it became, in all probability, more difficult to read the verniers.

The following little table contains the probable errors derived from Boss' formulæ for a mean of three observations, and of forty, from the better catalogues between 1830 and 1880:—

	3 Obs.		40 Obs.	
	Wt.	P.E.	Wt.	P.E.
Åbo, 1830	1·0	±0″·30	3·5	±0″·16
Dorpat, 1830	1·0	0·30	3.5	0·16
Airy, Cambridge	0·5	0·42	1·5	0·24
Edinburgh, 1837	0·7	0·36	1·5	0·24
Greenwich, 1840	0·5	0·42	2·0	0·21
Radcliffe, 1845	0·3	0·55	0·7	0·36
Armagh	0·2	0·67	0·4	0·47
Jacob, 1850	0·3	0·55	...	...
Greenwich, 1845	0·6	0·39	2·5	0·19
Greenwich, 1850	0·5	0·42	2·0	0·21
Paris (Laugier)	0·7	0·36	2·5	0·19
Greenwich, 1860	1·0	0·30	3·0	0·17
Paris, 1860	1·5	0·24	3·5	0·16
Brussels, 1860	0·6	0·39	2·0	0·21
Greenwich, 1864	1·0	0·30	3·0	0·17
Brussels, 1865	1·0	0·30	4·0	0·15
Melbourne, 1868	1·0	0·30	2·0	0·21
Greenwich, 1870	0·7	±0·36	2·0	±0·21

For the following catalogues little or no difference exists between the accuracy of the individual declinations, usually because the ordinary number of observations varies but little; in one or two of the less accurate catalogues because it is difficult to separate casual and constant error :—

Authority.	Usual No. Obs.	Boss' Weight.	Probable Error.	
			″	
Piazzi, 1800	...	0·1	±0·95*	* I ordinarily adopt ±0″·8 for the probable error of a declination from Piazzi.
Groombridge, 1810	6	0·3	±0·57	
Pond (Olufsen), 1822	...	1·0	±0·30	
Cape (Henderson)	...	1·0	±0·30	
Königsberg, 1838	...	0·6	±0·39	
Königsberg, 1843	40	1·5	±0·24	
Bonn, 1866	8	1·0	±0·30	
Leyden, 1866	...	5·0	±0·13	
Leipzig, 1867	...	1·0	±0·30	

Boss' discussion of the Pulkova declinations of 1845 refers to the first, less correct, edition; later the errors of division were more minutely allowed for, after the discovery of the scale by which Ertel subdivided the degrees on the vertical circle.

In some cases Professor Boss assigns weights (depending on more than forty observations) which equal that given to circumpolar or fundamental stars at Leyden. His maximum is 5·0, but is very rarely applied. We may safely consider that in no case is 5·0 on his scale exceeded during the period contained in his researches.

Professor Auwers has investigated the accuracy of the declinations of the Hauptsterne combined in the *Jahrbuch* Catalogue. The results are in part as follows, reduced from mean to probable error :—

Catalogue.	Date.	Max. Weight.	Probable Error. Max. Weight.	Probable Error. Unit Weight.
			″	″
Pulkova	1845	4	±0·15	±0·29
	1865	7	±0·16	
Greenwich	1861	3	±0·21	0·37
	1872	4	±0·18	0·35
Leyden	...	5	±0·19	0·42

The weight assigned to Pulkova 1865 is relatively high; the number of observations is frequently but four (double), and the invariable weight, 7, was assigned without knowledge of this

number. For the Leyden stars weight 5 was given to sixteen or more single observations.

We can now obtain an approximate idea of the general improvement of the accuracy of observations of declination during this century.

The catalogue of Piazzi is evidently less accurate than Auwers's *Bradley*, and requires re-reduction, as has long been known. Groombridge's declinations, usually depending on six observations, are affected with a probable error of $\pm 0''.57$ according to Boss, of $\pm 0''.53$ according to Auwers (see his paper in vol. lxiv. of the *Astronomische Nachrichten* many years ago). The Reichenbach circles, read by verniers, used by Bessel, Argelander, Struve, and others, leave a residual probable error of $\pm 0''.2$ (or perhaps less) depending on errors of division. The subdivision of the degrees on the circles may possibly have been effected by the same process as that of the Pulkova vertical circle, the work of Reichenbach's successor, Ertel. Errors of division of the same order are indicated by Professor Valentiner in his observations made at Karlsruhe with a reconstructed circle divided by Reichenbach. As the older Reichenbach circles were read by verniers it is difficult to trace the effects of division errors in the different minutes of the same degree. Argelander's estimate of $\pm 0''.208$ for the ultimate probable error of his results seems to be too large.

The English and French mural circles seem to have been excellently divided, at least for the time: this is shown by Professor Boss' estimates for the probable error of forty observations; for these instruments it is about $\pm 0''.20$.* The circles were at least occasionally moved into different positions with respect to the telescopes, and six microscopes were usually employed for the standard observations. The two circles used at Armagh and at Oxford up to about 1862 were less accurate. They are mounted as meridian circles, and divided on their faces.

The newer English transit circles, according to Boss' investigations, gave about the same probable error for forty observations; $\pm 0''.19$, including the two Greenwich Catalogues for 1860 and 1864, and the results which he has combined for 1870. Nearly the same value is obtainable from Professor Auwers's investigations. The Pulkova vertical circle was investigated by Boss from the older results for 1845, by Auwers from the newer.

The minimum probable error for this series, according to Boss, is, however, $\pm 0''.13$, according to Auwers $\pm 0''.15$; the variation is in the wrong direction. To explain this we have to note that probably the stars employed by Boss were those which had been most frequently observed; they were, at any rate, a selection from the Hauptsterne, while Auwers's catalogue and the *Jahrbuch* contain them all, with but few

* This does not include the inferior instruments used at Madras and the Cape before 1839.

exceptions. Boss' estimate of probable error is not strictly derived from his own investigation, but is confirmed by it.

For the Pulkova Catalogue of 1865 a minimum of four observations was considered sufficient. The probable casual error thence arising may be estimated in the mean at about ±0″·14 with a sensible decrease either for the stars observed below pole also, or more frequently observed above.

We can now make a comparison between the accuracy of the Greenwich results obtained from the mean of the two Seven-year Catalogues, as combined by Professor Auwers, and the combination of the Ten- and Five-year Catalogues. The probable error of weight 3 (more than fifteen observations in the two Seven-year Catalogues) is ±0″·165, according to my calculation. Auwers gives as *mean* error for weight 3 ±0″·318, which would give ±0″·214 for probable error. The difference is due to the fact that the latter value does not allow enough range in the scale of weights for Greenwich 1861. See *A.N.*, vol. cxiv. col. 14, where Professor Auwers makes a similar remark. The value ±0″·165 is now reduced at Greenwich to ±0″·114 for the general average of the zones not too far south.

We may for the moment adopt the hypothesis of a constant error to each star arising from uncorrected errors of division. The harmonic mean number of observations is approximately forty, and the average probable error of the mean not far from ±0″·09. Consequently

$$\pm 0''\cdot 14 = \sqrt{(0\cdot 165)^2 - (0\cdot 09)^2}$$

must be allowed for constant error on this hypothesis. The corresponding number for 1877–91 is

$$\pm 0''\cdot 06 = \sqrt{(0\cdot 114)^2 - (0\cdot 09)^2},$$

but this is rather uncertain. At any rate, the value ±0″·09 is an extreme limit of possible constant error for the fifteen years. The hypothesis is not entirely confirmed. It is safer, however, in determining a scale of weights to proceed cautiously in adopting any hypothesis as to the make-up of the probable errors, and obtain as nearly as possible empirical values of the probable error for different numbers of observations. The thing to be avoided is not so much apparent inequalities of slight amount in contemporaneous series which contain the same stars, as large errors in assigning relative weights to old work compared to new. Astronomers frequently make the mistake of overestimating the weight of a series which has been long known and used. The probable error of the declination of a Hauptstern from the *Jahrbuch* is now on the average ±0″·28, and for 1900 ±0″·31; while if the same star's declination has been largely observed about 1885 at the four observatories of Pulkova, Greenwich, the Cape, and Oxford (the Radcliffe), the probable error would be for 1885 but ±0″·07, for 1895 ±0″·09, for 1900

±0″·11. A star observed at Pulkova and Greenwich only would have a similar probable error for 1885 of ±0″·09, for 1895 ±0″·10, for 1900 ±0″·12; and the catalogue (Pulkova) which contains most fundamental stars would give alone for 1885 ±0″·13, for 1895 ±0″·14, for 1900 ±0″·15.

It is pretty clear that before using the *Jahrbuch* Catalogue definitely for any important purpose it will be well to wait for the completion of the revision now in progress. The general considerations just brought forward have another application, viz., to the arrangement of future observations.

Bringing together, then, in tabular form the results for the probable errors of the stars in various catalogues which have been observed the number of times adopted for standard declinations we have

Catalogue.	No. Obs. Harm. Mean.	Probable Error of Dec.	Internal P.E.	Constant Error.
		″	″	″
Greenwich, 1861 †	40	±0·165	±0·09	±0·14
Greenwich, 1872	38	±0·163	±0·09	±0·13
Greenwich, 1885 ‡	41	±0·114	±0·08	±0·08
Pulkova, 1865	4 or more ‖	±0·159	±0·11	±0·11
Pulkova, 1885	12 ‖	±0·131	±0·08	±0·10
Leyden, 1868	16 ¶	±0·188	±0·12	±0·14
Cape, 1885	19	±0·169	±0·12	±0·12
Oxford, 1885	15	±0·170	±0·13	±0·11
Greenwich, 1880 or 1890 §	9	±0·193	±0·18	±0·07

The "Internal P.E." is a rough estimate of the effect on the mean of the casual errors of the individual observations, and the quantities in the last column are very rough when derived, as in the last line, from the difference of squares of two nearly equal values. The quantities in the column of "Probable Error" are derived from Professor Auwers's researches for Pulkova 1865 and Leyden 1868; for the catalogues Greenwich 1861 and Greenwich 1872 they are taken from the residuals for weights 3 and 4 respectively in Publication 14 of the *Astronomische Gesellschaft*, with due allowances. Professor Auwers remarks in the article that the increase of precision with the number of observations is greater than had been supposed; which rendered it desirable to investigate these numbers independently rather than to give his probable error for weight 1 reduced by dividing by $\sqrt{3}$ and $\sqrt{4}$. This would have given ±0″·21 and ±0″·18 respectively.

It was with great regret that I gave up the idea of including

† Combined by Professor Auwers. ‡ 1880 and 1890 combined. § The catalogue which had less observations. ‖ Double observations. I have not the actual numbers. The number 12 is a rough approximation. ¶ Something must be added to this number for the circumpolar stars.

the observations made at Madison, Wisconsin, between 1887 and 1892. They are evidently excellent, but exhibit a periodicity in right ascension which far exceeds that shown in the other series. And one reason for this is plain: they do not include a sufficient number of 427-day periods of the latitude variations. The investigation of the detailed corrections necessary to eliminate the total variation of latitude would be too serious a matter for me to undertake for my present purpose; and it would seem unjust to the excellent series to apply empirical corrections. The numbers contained on pages 35 and 36 (publications of the Washburn Observatory 8) are not yet tabulated; if we should apply a rough interpolation from them, as I have inadvertently done in a few cases where I needed the results, we should make a mistake, because the mean difference of all the declinations is contained in both tables, and would thus be applied twice. One of the tables should have been first formed, its results subtracted from the individual differences, and the second table formed from the remainders; and another approximation to the first table might then be made if need be. Usually the $\Delta\delta_\delta$ are the more important, and should be first obtained; then the $\Delta\delta_\alpha$ and the revised values of the $\Delta\delta_\delta$. Whether the systematic corrections to the declinations are actually of the form of $f(\delta) + \psi(\alpha)$ is of course doubtful; and some astronomers seem to me to carry this form too far, especially when the observations so corrected are purely differential. In such cases one may suspect that agreement has been attained at the expense of truth. In this investigation I have pursued an extreme course in the other direction; have employed $\Delta\delta_\delta$, not from a curve, but from discontinuous averages; and have omitted $\Delta\delta_\alpha$ altogether. The result has been that my computed probable errors are rather too large; and the decided improvement visible in them since 1880 is certainly not overstated. I should be far from asserting that a constant error of $\pm 0''.10$ is inherent in Nyrén's admirable series. The average constant error of the catalogues here investigated, whose epochs are about 1885, is $\pm 0''.10$, and this seems to express a trustworthy result, as the smaller of the two values used to obtain it is substantially based upon the intercomparison of Greenwich and Pulkova: if the probable error of one is increased that of the other side will be diminished. The residual error of division for the Lund circle divided by the Repsolds, and in this similar to the Pulkova instrument in its present state, is $\pm 0''.065$ for four microscopes, or $\pm 0''.046$ for eight. At Greenwich $\pm 0''.16$ is allowed for this and other causes in weighting circumpolars; evidently too much. The probable error of six degree lines at Greenwich is about $\pm 0''.03$. The batches of six lines separately determined for polar stars and the nadir indicate a probable error of about $\pm 0''.04$ for the individual batch by comparing each with its neighbours. The other subdivisions of degrees have not been determined at Greenwich, and it is not easy to guess whether they would on the average

exhibit larger errors—possibly enough to fill the gap between $\pm 0''.04$ and $\pm 0''.08$.

The errors of division of the Leyden circle were determined for every line. The constant error of $\pm 0''.14$ indicated by Professor Auwers's researches must therefore be accounted for either by the casual errors of this determination, or by the variations of latitude during the comparatively short period included in the time of observation, or by unknown causes.

There seems to be no doubt, I may say in conclusion, that the accuracy of fundamental declinations has substantially gained during the past half-century, as well as during the century which preceded; and that the errors resulting from faulty divisions and serious flexures are now far less harmful than they formerly were.

Williamstown, Mass, U.S.A.:
1895 *May* 31.

Comparison of the Sun's Longitudes for 1900 *computed from Newcomb's Tables of the Sun with those computed from Le Verrier's Tables.* By A. M. W. Downing, M.A., D.Sc.

In view of the probability of the adoption of Professor Newcomb's Tables of the Sun in some, at all events, of the astronomical ephemerides at an early date, the publication of the following comparison may be of interest. It exhibits the corrections to apparent longitudes of the Sun, taken from Le Verrier's *Tables du Soleil*, deduced from the corresponding longitudes taken from Professor Newcomb's tables, at eight-day intervals during the year 1900. The materials for computing the latter longitudes have been communicated to me by Professor Newcomb, in advance of the publication of his tables, accompanied by his courteous permission to publish the results if I thought fit to do so.

The mean of the forty-six individual corrections for the year is $-0''.485$. It should be pointed out, however, that the value of the constant of aberration adopted by Professor Newcomb is $20''.50$, whilst that adopted in Le Verrier's tables in $20''.45$. If the same value of the constant be adopted in both tables the mean correction to Le Verrier becomes $-0''.435$.

Longitudes of Sun 1900.

Corrections to Le Verrier's Tables.

Day.	Correction.	Day.	Correction.	Day.	Correction.
	″		″		″
Jan. 1	−0·43	May 9	−0·04	Sept. 6	−0·84
9	−0·50	17	+0·12	14	−0·87
17	−0·32	25	+0·09	22	−0·93
25	−0·19	June 2	−0·07	30	−1·08
Feb. 2	−0·27	10	−0·07	Oct. 8	−0·97
10	−0·22	18	−0·04	16	−0·93
18	−0·07	26	−0·16	24	−1·17
26	+0·02	July 4	−0·43	Nov. 1	−1·24
Mar. 6	−0·10	12	−0·42	9	−1·09
14	−0·07	20	−0·35	17	−1·13
22	+0·12	28	−0·56	25	−1·25
30	+0·01	Aug. 5	−0·75	Dec. 3	−1·10
Apr. 7	−0·01	13	−0·70	11	−0·93
15	+0·06	21	−0·70	19	−0·95
23	+0·01	29	−0·82	27	−0·97
May 1	+0·01				

Nautical Almanac Office:
1895 *September* 9.

Description of a Mechanical Apparatus for computing Refractions.

By W. E. Cooke.

(*Communicated by Sir Charles Todd.*)

This consists essentially of two scales, B and F, sliding in parallel grooves, a movable pointer, P (shaded in the diagram), and two fixed scales for barometer and thermometer respectively.

A, C, E, G are narrow strips of metal serving as guides to the movable portions.

B is a strip of brass, 21 in. × 3 in. × $\frac{3}{16}$, on which are ruled divisions as follows: 17 longitudinal lines divide it into 18 rows, the fourth line from the top being rather thicker than the others. In making the short vertical graduations two different scales were used, one inch representing ·0200 for the first four rows, and three inches representing the same quantity for the remaining 14. The commencement of each row represents successively the logs. 0·3200, 0·6200, 0·9200, 1·2200, 1·4700, 1·5200, 1·5700, &c., to 2·1200, and the figures inscribed are the antilogs corresponding to the scale numbers thus obtained. (It will be noticed that the antilogs overlap, *i.e.* the figures at the end of

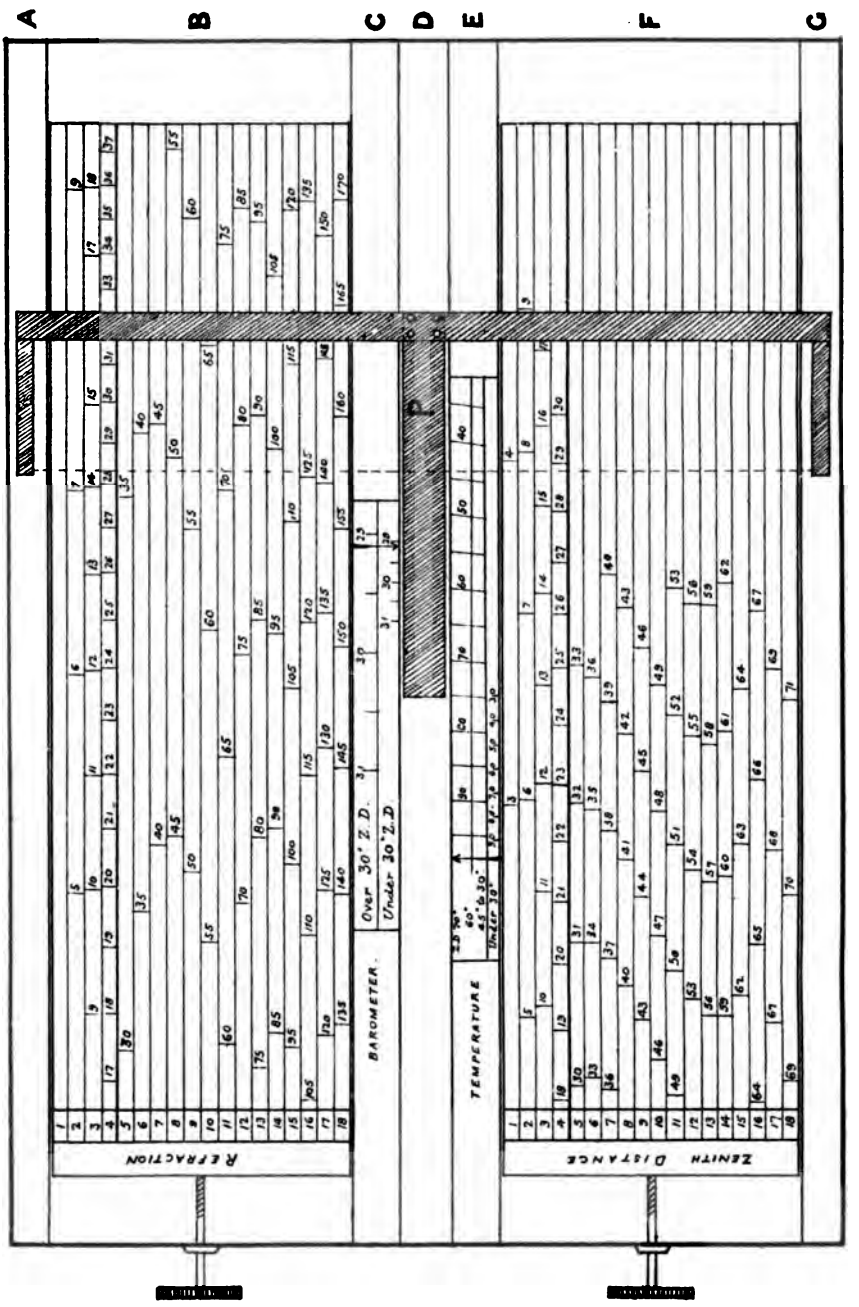
each row are repeated at the commencement of the next; the amount of this overlap corresponds to at least ·0720.)

F is of the same width and thickness, but need not necessarily be quite as long as B, for very little overlap is required. The same scales as before are used. The commencement of each row represents successively 0·3000, 0·6000, 0·9000, 1·2000, 1·4500, 1·5000, 1·5500, &c., up to 2·1000, and the figures inscribed are the Z.D.s which correspond to the various logs according to the refraction tables published as an appendix to the Greenwich Observations of 1836. These extend from 3° to 71° Z.D.

B and F are each provided with a fine pointer which extends at right angles across the strips C and E respectively. These pointers may be affixed to any part of the edge. The movable (shaded) pointer, P, consists of a fine black thread stretched at right angles to B and F on a frame which slides in the groove D. The arm of this pointer is for convenience graduated from 1 to 18 to correspond with the rows in B and F. The barometer scale on C is laid down as follows. A point is arbitrarily selected, and the scale, with the graduations increasing to the left, is placed so that this arbitrary point reads 0·0200. The barometer readings corresponding to the various logs. as given in Table I. of the "Appendix" are then plotted, each scale being, of course, employed in turn. For the temperature curve a little more care is required, for it becomes necessary to employ Tables II. and IV. To obtain the zero point, B and F are moved until the pointer of B is on ·0200 of the barometric scale and the initial lines on B and F are collinear (as indicated by the movable thread); the pointer of F will now indicate the zero point for temperature. The small scale (giving Z.D.s 0° to 30°) can be used in a similar manner to that just indicated for the barometer, but the logs must increase to the left, and the zero point will correspond to ·0000. With the large scale the temperatures can also be put down from Table II., and these will be the correct readings for Z.D.s up to 45°. In order to obtain the top line (Z.D. 70°) we must add together the figures for 70° Z.D. in Table IV. and those in Table II. We now connect corresponding points by short straight lines, and intermediate longitudinal lines can be drawn to represent the various Z.D.s between 45° to 70°. (I am afraid that in the diagram the line for 60° Z.D. is not very accurately laid down.)

To use the apparatus.—Move B, by means of the slow-motion screw, until the pointer stands opposite the correct barometer reading; move F to the proper temperature reading, and move the thread to the proper reading of Z.D., as shown in one or other of the rows on F. The thread reading on the corresponding row of B will be the refraction required.

It will be found that if this apparatus be carefully graduated on the scale indicated, refractions can be obtained with certainty to the nearest tenth of a second of arc, and with a little care the error will never exceed two or three hundredths.



APPARATUS FOR COMPUTING REFRACTIONS.

J. PATTISON COPE & CO. LITH. LONDON

Observations of Phenomena of Jupiter's Satellites with the 8-inch Equatorial at Windsor, New South Wales, in the year 1895.
By John Tebbutt.

Day of Obs.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation.	Mean Time of *N. Almanac.*
					h m s	h m s
Feb. 4	III.	Ecl. R.	First seen	74	23 50 20	23 52 42
4	III.	,,	Full brightness	,,	23 57 8	
8	I.	,,	First seen	,,	0 13 44	0 14 17
8	I.	,,	Full brightness	,,	0 17 40	
11	III.	Occ. R.	First seen	132	23 23 15	
11	III.	,,	Bisection	,,	23 24 25	23 30
11	III.	,,	Last contact	,,	23 26 6	
12	III.	Ecl. D.	Began to fade	74	0 57 27	
12	III.	,,	Last seen	,,	1 5 35	1 3 59
14	I.	Occ. D.	First contact	168	22 44 14	
14	I.	,,	Bisection	,,	22 46 44	22 48
14	I.	,,	Last seen	,,	22 48 39	
15	II.	Ecl. R.	First seen	74	21 44 8	21 45 25
15	II.	,,	Full brightness	,,	21 46 51	
15	I.	Tr. Egr.	Int. contact	,,	22 15 41	
15	I.	,,	Bisection	,,	22 17 36	22 20
15	I.	,,	Ext. contact	,,	22 20 35	
22	I.	Tr. Ingr.	Ext. contact	200	21 54 41	
22	I.	,,	Bisection	,,	21 56 58	21 54
23	I.	Ecl. R.	First seen	74	22 34 1	22 34 28
23	I.	,,	Full brightness	,,	22 37 26	
Mar. 1	III.	Tr. Egr.	Bisection	,,	20 58 38	21 0
1	III.	,,	Ext. contact	,,	21 5 22	
1	II.	Occ. D.	First contact	132	21 46 2	
1	II.	,,	Bisection	,,	21 48 30	21 50
1	II.	,,	Last seen	,,	21 51 54	
1	I.	Tr. Ingr.	Ext. contact	,,	23 48 33	
1	I.	,,	Bisection	,,	23 49 30	23 46
1	I.	,,	Int. contact	,,	23 50 50	
3	I.	Tr. Egr.	Ext. contact	,,	20 27 42	
3	I.	,,	Bisection	,,	20 29 12	20 30
3	I.	,,	Ext. contact	,,	20 32 7	
7	IV.	Occ. R.	Last contact	74	21 8 19	20 33
11	I.	Ecl. R.	First seen	,,	20 54 21	20 54 57

Day of Obs.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation.	Mean Time of *N. Almanac.*
					h m s	h m s
Mar. 18	I.	Ecl. R.	First seen	74	22 50 12	22 50 42
18	I.	,,	Full brightness	,,	22 53 50	
25	I.	Occ. D.	First contact	168	21 10 2	
25	I.	,,	Bisection	,,	21 12 26	21 13
25	I.	,,	Last seen	,,	21 13 36	
Apr. 3	I.	Ecl. R.	First seen	74	21 10 36	21 11 0
3	I.	,,	Full brightness	,,	21 14 26	
9	I.	Tr. Ingr.	Ext. contact	,,	22 17 28	
9	I.	,,	Bisection	,,	22 20 47	22 20
9	I.	,,	Int. contact	,,	22 23 37	
10	IV.	Ecl. R.	First seen	138	21 39 19	21 52 36
10	IV.	,,	Full brightness	,,	21 55 22	
20	II.	Ecl. R.	First seen	,,	21 3 34	21 4 45
20	II.	,,	Full brightness	,,	21 7 6	
24	III.	,,	First seen	,,	20 6 49	20 8 30
24	III.	,,	Full brightness	,,	20 14 36	
26	I.	,,	First seen	,,	21 26 27	21 26 41
May 12	I.	,,	First seen	74	19 45 55	19 46 13
12	I.	,,	Full brightness	,,	19 49 20	

Remarks.

Feb. 4.—Clear sky, but moon present.

Feb. 8.—Sky beautifully clear and images steady and well defined.

Feb. 11.—Sky clear and definition pretty good; the first phase observed rather late.

Feb. 12.—Steadiness and definition very satisfactory. First phase noted late; the satellite had certainly faded as compared with the other satellites. I thought I could again see the satellite for moment, eight seconds after the recorded time of disappearance.

Feb. 14.—Images rather tremulous, particularly at final disappearance.

Feb. 15.—II. suspected at recorded time; I was certain of it three seconds later. The planet had just emerged from a thin cloud. Definition of I. pretty good.

Feb. 22.—Good definition at external contact, but not so at bisection.

Feb. 23.—Sky beautifully clear with good definition; moon absent.

Mar. 1.—Planet badly defined and boiling. Bisection of III. very unsatisfactory; definition better at external contact. Images steady and fairly defined at ingress of I., but external contact noted rather late in consequence of cloud.

Mar. 3.—Images steady and well defined. The shadows of I. and II. were at the same time on the disc. The shadow of I., the further one from the centre of the disc, was projected on a bright zone, and appeared as a dark, hazy spot, while the shadow of II. was seen as a perfectly black spot on one of the dark belts of the planet.

Mar. 11.—Steadiness and definition satisfactory.

Mar. 18.—Clear sky, but images somewhat tremulous.

Mar. 25.—Fair definition.

Apr. 3.—Sky clear and definition good, but images slightly tremulous.

Apr. 9.—Planet low and boiling, and observations unsatisfactory.

Apr. 10.—Sky beautifully clear, and planet low; the images, however, were pretty steady and well defined. This was the first eclipse visible here of the new cycle. The observer's position was taken at the telescope about 16 min. before the time of the *Nautical Almanac*, and the satellite was first seen as a very small brownish speck.

Apr. 20.—Definition fairly good, but images slightly tremulous. Observation of first appearance possibly a second late.

Apr. 24.—Sky beautifully clear. On the whole the planet was pretty well defined, but the limb occasionally boiled.

Apr. 26.—Sky beautifully clear, but planet low and boiling.

May 12.—Sky beautifully clear, but twilight pretty strong; planet's limb occasionally boiled.

Note.—An occulting bar was not employed in the eclipse observations. The times given in the first and sixth columns are the Windsor mean times of observation diminished by $10^h\ 3^m\ 20^s{\cdot}5$ and entered to the nearest second. The observations of full brightness in the eclipses are at the best only roughly approximate. In determining these times the increasing light of the satellite was repeatedly compared with the other visible satellites.

Private Observatory, Windsor, N.S. Wales:
1895 *June* 22.

Results of Micrometer Comparisons of Saturn and κ Virginis, 1895 May. By John Tebbutt.

During the close approach of *Saturn* to *κ Virginis* in May last I availed myself of the opportunity for securing a careful series of filar micrometer comparisons of the planet with the 8-inch equatorial. Comparisons were made on six nights under the most satisfactory conditions, the images being steady and well defined. A magnifying power of 74 diameters was employed throughout. On each of the first five evenings ten comparisons of the planets *preceding* and *north*, and the same number of the *following* and *south* limbs were made, in order to eliminate as much as possible any effect due to an error of the tabular semidiameter of the planet. On the last evening five comparisons only were obtained of each pair of corresponding limbs. The differential measures have been corrected for the tabular semidiameter, refraction, and a small inclination of the transit thread to the meridian when the distance threads were set parallel to the equator. The star's mean place for 1895·0 has been adopted as R.A.$=14^h\ 7^m\ 17^s{\cdot}59$, N.P.D.$=99°\ 47'\ 5''{\cdot}8$ from the Greenwich Five-Year Catalogue of 258 Fundamental Stars for 1890. Considering the excellent conditions for observing, and the almost absolute accuracy of the place of the comparison star, I venture to think that the results as given in the accompanying table will prove as satisfactory as any derived from observations on the meridian. The last column of the table exhibits the resulting errors of the ephemeris on page 260 of the *Nautical Almanac*. The reductions plainly indicate that the semidiameter of the *Nautical Almanac* is somewhat too small. Measures of *Venus* and *ε Geminorum* were obtained on May 19 and 20, but the objects were so badly defined and tremulous that the results are scarcely worth publication.

Results of Micrometer Comparisons of Saturn and κ Virginis.

1895.	Windsor Mean Time.	Diff. R.A. Planet's Centre—Star.	Correction for Parallax.	Adopted Apparent R.A. of Star.	Geocentric Apparent R.A. of Planet's Centre from Observation.	Geocentric Apparent R.A. of Planet's Centre from *Nautical Almanac.*	Diff. *N.A.*—Obs.
	h m s	m s	s	h m s	h m s	s	s
May 6	10 7 7	− 0 19·94	−0·02	14 7 20·01	14 7 0·95	1·12	+0·17
7	8 45 49	− 0 34·9	−0·03	14 7 20·01	14 6 45·07	45·25	+0·18
9	9 21 42	− 1 8·62	−0·02	14 7 20·02	14 6 11·38	11·52	+0·14
13	8 26 38	− 2 13·09	−0·03	14 7 20·04	14 5 6·92	7·13	+0·21
15	8 34 15	− 2 44·81	−0·03	14 7 20·05	14 4 35·21	35·43	+0·22
16	8 50 56	− 3 0·40	−0·02	14 7 20·05	14 4 19·63	19·72	+0·09

1895.	Windsor Mean Time.	Diff. N.P.D. Planet's Centre —Star.	Correction for Parallax.	Adopted Apparent N.P.D. of Star.	Geocentric Apparent N.P.D. of Planet's Centre from Observation.	Geocentric Apparent N.P.D. of Planet's Centre from *Nautical Almanac.*	Diff. *N.A.*—Obs.
	h m s	′ ″	″	° ′ ″	° ′ ″	″	″
May 6	10 7 7	+ 11 19·8	+0·4	99 47 23·6	99 58 43·8	44·8	+1·0
7	8 45 49	+ 10 0·0	+0·4	99 47 23·6	99 57 24·0	25·3	+1·3
9	9 21 42	+ 7 11·7	+0·4	99 47 23·6	99 54 35·7	37·3	+1·6
13	8 26 38	+ 1 54·3	+0·4	99 47 23·6	99 49 18·3	20·1	+1·8
15	8 34 15	− 0 40·0	+0·4	99 47 23·6	99 46 44·0	46·1	+2·1
16	8 50 56	− 1 55·8	+0·4	99 47 23·6	99 45 28·2	30·1	+1·9

Private Observatory, Windsor, N. S. Wales:
1895 June 2.

Errata in Mr. Tebbutt's Measures of Double Stars, MONTHLY NOTICES, *March* 1895.

Page 308, opposite to Ref. No. 11 and under "Eyes," *for* P *read* R.

Page 310, opposite to Ref. No. 60 and under "Distance," *for* ·88 *read* 2·88.

Page 311, opposite to Ref. No. 64 and under "Hour Angles," *for* 3 7 W *read* 3 47 W.

Ephemeris for Physical Observations of Jupiter,

Greenwich Noon.		Position-angle of ℳ's Axis. P	L−O	Diff.	B	Annual Parallax. A−L	Apparent Diameter. Equat. 2a	Defect.	Polar. 2b
1896.		°	°		°	°	″	″	″
Jan.	1	16·570	351·618	221	+0·439	−4·751	45·75	0·08	42·88
	3	16·494	351·397	229	·440	4·368	45·89	·07	43·01
	5	16·416	351·168	236	·442	3·978	46·01	·06	43·13
	7	16·335	350·932	243	·444	3·581	46·13	·05	43·23
	9	16·251	350·689	248	·446	3·177	46·23	·04	43·33
	11	16·164	350·441	254	+0·448	−2·768	46·32	0·03	43·41
	13	16·076	350·187	258	·451	2·354	46·40	·02	43·49
	15	15·986	349·929	262	·454	1·935	46·46	·01	43·55
	17	15·894	349·667	265	·458	1·512	46·51	·00	43·59
	19	15·800	349·402	266	·462	1·087	46·55	...	43·63
	21	15·705	349·136	268	+0·466	−0·660	46·57	...	43·65
	23	15·610	348·868	268	·470	−0·231	46·58	...	43·66
	25	15·514	348·600	267	·474	+0·198	46·57	...	43·65
	27	15·418	348·333	266	·479	0·626	46·56	...	43·63
	29	15·322	348·067	263	·484	1·052	46·52	·00	43·60
	31	15·226	347·804	261	+0·488	+1·476	46·48	0·01	43·56
Feb.	2	15·131	347·543	258	·493	1·897	46·42	·01	43·51
	4	15·036	347·285	254	·498	2·315	46·35	·02	43·44
	6	14·943	347·031	248	·503	2·730	46·26	·03	43·36
	8	14·852	346·783	242	·508	3·138	46·16	·03	43·27
	10	14·762	346·541	236	+0·513	+3·541	46·05	0·04	43·16
	12	14·674	346·305	230	·518	3·937	45·93	·05	43·05
	14	14·589	346·075	222	·524	4·327	45·80	·06	42·92
	16	14·506	345·853	213	·529	4·709	45·65	·08	42·79
	18	14·426	345·640	204	·534	5·082	45·50	·09	42·64
	20	14·349	345·436	194	+0·538	+5·446	45·33	0·10	42·49
	22	14·276	345·242	184	·543	5·800	45·16	·12	42·33
	24	14·206	345·058	174	·548	6·144	44·98	·13	42·15
	26	14·140	344·884	163	·552	6·478	44·78	·14	41·97

1895–96. (*Concluded.*) By A. Marth.

Greenwich Noon.	Brightness in Star Magn.	Longitude of ℳ's Central Meridian. ($877°{\cdot}90$) I.	($870°{\cdot}27$) II.	Corr. for Phase.	Light-time.	A−O	B
1896.	m	°	°	°	m	°	°
Jan. 1	−2·11	223·19	225·18	+0·10	36·407	346·8694	+0·6954
3	−2·12	179·27	166·01	·08	36·298	347·0305	·6870
5	−2·12	135·36	106·84	·07	36·199	347·1916	·6786
7	−2·13	91·45	47·67	·06	36·109	347·3526	·6701
9	−2·13	47·55	348 50	·04	36·030	347·5136	·6617
11	−2·14	3·64	289·33	+0·03	35·961	347·6745	+0·6532
13	−2·14	319·73	230·16	·02	35·901	347·8354	·6448
15	−2·14	275·82	170·99	·02	35·852	347·9962	·6364
17	−2·15	231·90	111·81	·01	35·813	348·1570	·6279
19	−2·15	187·98	52·63	·01	35·785	348·3178	·6195
21	−2·15	144·06	353·45	+0·00	35·767	348·4786	+0·6110
23	−2·15	100·13	294·76	...	35·760	348·6393	·6026
25	−2·15	56·20	235·07	...	35·764	348·8000	·5941
27	−2·15	12·26	175·87	...	35·778	348·9606	·5857
29	−2·15	328·31	116·66	·00	35·803	349·1211	·5772
31	−2·14	284·35	57·44	−0·01	35·838	349·2816	+0·5687
Feb. 2	−2·14	240·38	358·21	·02	35·884	349·4420	·5603
4	−2·14	196·40	298·97	·02	35·939	349·6024	·5518
6	−2·13	152·42	239·73	·03	36·005	349·7628	·5434
8	−2·13	108·42	180·47	·04	36·082	349·9232	·5349
10	−2·12	64·41	121·20	−0·05	36·168	350·0835	+0·5264
12	−2·11	20·39	61·92	·07	36·264	350·2437	·5180
14	−2·11	336·35	2·62	·08	36·370	350·4039	·5095
16	−2·10	292·30	303·32	·10	36·485	350·5641	·5011
18	−2·09	248·24	244·00	·11	36·609	350·7242	·4926
20	−2·08	204·16	184·66	−0·13	36·743	350·8843	+0·4841
22	−2·08	160·07	125·31	·15	36·885	351·0444	·4757
24	−2·07	115·96	65·94	·16	37·035	351·2044	·4672
26	−2·06	71·84	6·56	·18	37·194	351·3643	·4587

Greenwich Noon.	Position-angle of ♃'s Axis. P	L−O	Diff.	B	Annual Parallax. A−L	Apparent Diameter. Equat. sa	Defect.	Polar. sb
1896.	°	°		°	°	″	″	″
Feb. 28	14·078	344·721	153	+ ·556	+ 6·802	44·58	·16	41·79
Mar. 1	14·020	344·568	141	+0·560	+ 7·114	44·38	0·17	41·59
3	13·966	344·427	129	·564	7·415	44·16	·18	41·39
5	13·916	344·298	118	·568	7·704	43·94	·20	41·18
7	13·871	344·180	105	·571	7·981	43·72	·21	40·97
9	13·831	344·075	93	·574	8·246	43·49	·22	40·76
11	13·795	343·982	80	+0·577	+ 8·498	43·25	0·24	40·54
13	13·764	343·902	68	·580	8·738	43·01	·25	40·31
15	13·738	343·834	55	·582	8·966	42·77	·26	40·08
17	13·717	343·779	42	·584	9·181	42·52	·27	39·85
19	13·701	343·737	28	·586	9·382	42·27	·28	39·62
21	13·689	343·709	16	+0·587	+ 9·570	42·02	0·29	39·39
23	13·683	343·693	3	·588	9·745	41·77	·30	39·15
25	13·682	343·690	9	·589	9·908	41·52	·31	38·91
27	13·685	343·699	22	·590	10·058	41·27	·32	38·68
29	13·694	343·721	35	·590	10·195	41·01	·32	38·44
31	13·707	343·756	47	+0·590	+ 10·319	40·76	0·33	38·20
Apr. 2	13·725	343·803	60	·590	10·431	40·51	·33	37·96
4	13·748	343·863	72	·589	10·531	40·25	·34	37·73
6	13·776	343·935	83	·588	10·618	40·00	·34	37·49
8	13·808	344·018	96	·586	10·693	39·75	·35	37·26
10	13·845	344·114	108	+0·584	+ 10·757	39·50	0·35	37·02
12	13·886	344·222	120	·582	10·808	39·26	·35	36·79
14	13·932	344·342	131	·579	10·847	39·01	·35	36·56
16	13·982	344·473	142	·576	10·875	38·77	·35	36·34
18	14·036	344·615	154	·573	10·892	38·53	·35	36·11
20	14·095	344·769	164	+0·570	+ 10·898	38·30	0·35	35·89
22	14·158	344·933	174	·566	10·892	38·06	·34	35·67
24	14·224	345·107	185	·561	10·876	37·83	·34	35·46
26	14·294	345·292	194	·557	10·851	37·61	·34	35·25
28	14·367	345·486	205	·552	10·815	37·38	·33	35·04

Greenwich Noon. 1896.	Brightness in Star Magn. m	Longitude of ℳ's Central Meridian. ($877^{\circ}{\cdot}90$) I. °	($870^{\circ}{\cdot}27$) II. °	Corr. for Phase. °	Light-time. m	A−O °	B °
Feb. 28	−2·05	27·70	307·16	− ·20	37·361	351·5242	+ ·4502
Mar. 1	−2·03	343·55	247·75	−0·22	37·535	351·6841	+0·4417
3	−2·02	299·38	188·32	·24	37·717	351·8439	·4333
5	−2·01	255·19	128·87	·26	37·906	352·0037	·4248
7	−2·00	210·99	69·41	·28	38·102	352·1635	·4163
9	−1·99	166·77	9·93	·30	38·304	352·3232	·4078
11	−1·98	122·54	310·44	−0·32	38·513	352·4829	+0·3993
13	−1·96	78·29	250·93	·33	38·727	352·6425	·3908
15	−1·95	34·02	191·41	·35	38·947	352·8021	·3823
17	−1·94	349·74	131·87	·37	39·172	352·9617	·3738
19	−1·92	305·44	72·31	·38	39·402	353·1212	·3653
21	−1·91	261·13	12·74	−0·40	39·637	353·2807	+0·3568
23	−1·90	216·80	313·15	·41	39·876	353·4401	·3483
25	−1·88	172·45	253·54	·43	40·119	353·5995	·3398
27	−1·87	128·09	193·92	·44	40·365	353·7589	·3313
29	−1·86	83·72	134·29	·45	40·615	353·9182	·3228
31	−1·84	39·33	74·64	−0·46	40·867	354·0775	+0·3143
Apr. 2	−1·83	354·93	14·98	·47	41·123	354·2367	·3058
4	−1·81	310·51	315·31	·48	41·380	354·3959	·2973
6	−1·80	266·08	255·62	·49	41·640	354·5551	·2888
8	−1·79	221·64	195·92	·50	41·902	354·7142	·2803
10	−1·77	177·18	136·20	−0·50	42·165	354·8733	+0·2718
12	−1·76	132·71	76·47	·51	42·430	355·0323	·2633
14	−1·74	88·23	16·73	·51	42·696	355·1913	·2548
16	−1·73	43·74	316·98	·51	42·962	355·3503	·2463
18	−1·72	359·23	257·22	·52	43·228	355·5093	·2378
20	−1·70	314·71	197·45	−0·52	43·495	355·6682	+0·2293
22	−1·69	270·19	137·66	·52	43·761	355·8271	·2208
24	−1·68	225·65	77·86	·51	44·027	355·9859	·2123
26	−1·66	181·10	18·06	·51	44·293	356·1449	·2038
28	−1·65	136·55	318·25	·51	44·557	356·3034	·1953

Greenwich Noon.	Position-angle of ♃'s Axis. P	L−O.	Diff.	B	Annual Parallax. A−L.	Apparent Diameter. Equat. 2a	Defect.	Polar. 2b
1896.	°	°		°	°	″	″	″
Apr. 30	14·444	345·691	215	+0·547	+10·769	37·16	0·33	34·83
May 2	14·525	345·906	224	·541	10·713	36·95	·32	34·63
4	14·609	346·130	233	·535	10·647	36·74	·32	34·43
6	14·696	346·363	241	·529	10·573	36·53	·31	34·23
8	14·786	346·604	251	·523	10·490	36·32	·30	34·04
10	14·879	346·855	260	+0·516	+10·397	36·12	0·30	33·85
12	14·975	347·115	268	·508	10·296	35·92	·29	33·67
14	15·073	347·383	275	·500	10·187	35·73	·28	33·49
16	15·174	347·658	284	·492	10·069	35·54	·27	33·31
18	15·277	347·942	291	·484	9·944	35·36	·27	33·14
20	15·383	348·233	298	+0·475	+9·812	35·18	0·26	32·97
22	15·491	348·531	306	·466	9·672	35·00	·25	32·81
24	15·601	348·837	313	·457	9·524	34·83	·24	32·65
26	15·713	349·150	319	·448	9·370	34·67	·23	32·49
28	15·827	349·469	325	·438	9·209	34·50	·22	32·34
30	15·942	349·794	332	+0·428	+9·042	34·34	0·21	32·19
June 1	16·059	350·126	338	·417	8·868	34·19	·20	32·05
3	16·178	350·464	344	·407	8·688	34·04	·20	31·91
5	16·298	350·808	350	·396	8·502	33·90	·19	31·77
7	16·420	351·158	355	·385	8·310	33·76	·18	31·64
9	16·542	351·513	360	+0·373	+8·113	33·62	0·17	31·51
11	16·666	351·873	365	·361	7·911	33·49	·16	31·39
13	16·790	352·238	370	·349	7·703	33·36	·15	31·27
15	16·916	352·608	375	·336	7·490	33·24	·14	31·15
17	17·042	352·983	380	·324	7·273	33·12	·13	31·04
19	17·169	353·363	384	+0·311	+7·051	33·00	0·12	30·93
21	17·296	353·747		0·298	6·825	32·89	·12	30·83

Greenwich Noon. 1896.	Brightness in Star Magn.	Longitude of ☽'s Central Meridian. (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O	B
	m	°	°	°	m	°	°
Apr. 30	−1·64	91·98	258·42	−0·50	44·821	356·4621	+0·1868
May 2	−1·62	47·41	198·59	·50	45·083	356·6208	·1783
4	−1·61	2·83	138·75	·49	45·343	356·7794	·1698
6	−1·60	318·24	78·90	·49	45·602	356·9380	·1613
8	−1·59	273·64	19·04	·48	45·859	357·0965	·1528
10	−1·57	229·03	319·17	−0·47	46·114	357·2550	+0·1443
12	−1·56	184·42	259·30	·46	46·366	357·4134	·1359
14	−1·55	139·80	199·42	·45	46·616	357·5718	·1274
16	−1·54	95·17	139·54	·44	46·863	357·7302	·1189
18	−1·53	50·54	79·65	·43	47·106	357·8886	·1104
20	−1·52	5·90	19·75	−0·42	47·347	358·0470	+0·1019
22	−1·50	321·26	319·85	·41	47·584	358·2053	·0935
24	−1·49	276·61	259·94	·39	47·818	358·3636	·0850
26	−1·48	231·96	200·03	·38	48·048	358·5218	·0765
28	−1·47	187·30	140·12	·37	48·274	358·6800	·0680
30	−1·46	142·64	80·20	−0·36	48·496	358·8381	+0·0595
June 1	−1·45	97·98	20·27	·34	48·715	358·9962	·0511
3	−1·44	53·31	320·35	·32	48·929	359·1542	·0426
5	−1·43	8·64	260·42	·31	49·138	359·3122	·0341
7	−1·43	323·96	200·48	·30	49·343	359·4702	·0256
9	−1·42	279·28	140·55	−0·29	49·543	359·6282	+0·0171
11	−1·41	234·60	80·61	·27	49·739	359·7861	·0087
13	−1·40	189·92	20·67	·26	49·930	359·9440	+0·0002
15	−1·39	145·24	320·73	·24	50·115	0·1018	−0·0083
17	−1·38	100·55	260·78	·23	50·295	0·2596	·0168
19	−1·38	55·87	200·84	−0·22	50·470	0·4173	−0·0253
21	−1·37	11·18	140·89	·20	50·640	0·5750	·0338

The following is a list (continued from p. 493) of Greenwich mean times when the zero-meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc :—

1896.		I. (877°·90) h m	II. (870°·27) h m
Jan.	1	3 44·2	3 42·9
		13 34·6	13 38·5
	2	9 15·4	9 29·6
		19 5·8	19 25·2
	3	4 56·2	5 20·8
		14 46·7	15 16·4
	4	10 27·5	11 7·5
		20 17·9	21 3·1
	5	6 8·3	6 58·7
		15 58·7	16 54·3
	6	11 39·5	12 45·5
		21 30·9	22 41·0
	7	7 20·3	8 36·6
		17 10·7	18 32·2
	8	3 1·1	4 27·8
		12 51·5	14 23·4
	9	8 32·4	10 14·5
		18 22·8	20 10·1
	10	4 13·2	6 5·7
		14 3·6	16 1·3
	11	9 44·4	11 52·4
		19 34·8	21 48·0
	12	5 25·2	7 43·6
		15 15·6	17 39·2
	13	10 56·4	3 34·8
		20 46·8	13 30·4
	14	6 37·2	9 21·5
		16 27·6	19 17·1
	15	12 8·4	5 12·7
		21 58·8	15 8·3
	16	7 49·3	10 59·4
		17 39·7	20 55·0
	17	3 30·1	6 50·6
		13 20·5	16 46·2
	18	9 1·3	2 41·7
Jan.	18	12 7	Sat. III. Shadow crossing central Meridian.
		18 51·7	12 37·3
	19	4 42·1	8 28·5
		14 32·5	18 24·1
	20	10 13·3	4 19·7
		20 3·7	14 15·2
	21	5 54·1	10 6·4
		15 44·6	20 2·0
	22	11 25·4	5 57·6
		21 15·8	15 53·2
	23	7 6·2	11 44·3
		16 56·6	21 39·9
	24	2 47·0	7 35·5
		7 9	♃'s centre 84″·0 south of * 9ᵐ·2 B.D. 20°·2106.
		12 37·4	17 31·1
		16 30	♃'s centre 47″·2 south of * 9ᵐ·0 B.D. 20°·2104.
	25	8 18·2	3 26·7
		16 7	Sat. III. Sh.
		18 8·6	13 22·3
	26	3 59·1	9 13·4
		13 49·5	19 9·0
	27	9 30·3	5 4·6
		19 20·7	15 0·2
	28	5 11·1	10 51·4
		15 1·5	20 47·0
	29	10 42·4	6 42·6
		20 32·8	16 38·2
	30	6 23·3	2 33·8
		16 13·6	12 29·4
	31	2 4·1	8 20·6
		11 54·5	18 16·2
Feb.	1	7 35·4	4 11·8

1896.		I. (877°·90) h m	II. (870°·27) h m
Feb.	1	17 25 8	14 7·4
		20 6	Sat. III. Sh.
	2	3 16·2	9 58·6
		13 6·6	19 54·2
	3	8 47·5	5 49·8
		18 37·9	15 45·4
	4	4 28·3	11 36·6
		14 18·8	21 32·2
	5	9 59·6	7 27·8
		19 50·1	17 23·4
	6	5 40·5	3 19·0
		15 30·9	13 14·6
	7	11 11·8	9 5·9
		21 2·2	19 1·5
	8	6 52·7	4 57·1
		16 43·1	14 52·7
	9	2 33·6	10 43·9
		12 24·0	20 39·6
	10	8 4·9	6 35·2
		17 55·3	16 30·8
	11	3 45·8	2 26·4
		13 36·2	12 22·0
	12	9 17·1	8 13·3
		19 7·6	18 8·9
	13	4 58·0	4 4·5
		14 48·5	14 0·2
	14	10 29·4	9 51·4
		18 20	Sat. IV. Sh.
		20 10·8	19 47·1
	15	6 10·3	5 42·7
		16 0·7	15 38·3
	16	1 51·2	1 33·9
		11 41·6	11 29·6
		21 32·1	21 25·2
	17	7 22·6	7 20·8
		17 13·0	17 16·5
	18	3 3·5	3 12·1
		12 53·9	13 7·7

1896.		I. (877°·90) h m	II. (870°·27) h m
Feb.	19	8 34·9	8 59·0
		18 25·4	18 54·7
	20	4 15·8	4 50·3
		14 6·3	14 46·0
	21	9 47·2	10 37·3
		19 37·7	20 32·9
	22	5 28·2	6 28·6
		15 18·6	16 24·2
	23	1 9·1	2 19·9
		8 4	Sat. III. Sh.
		10 56·9	12 15·5
	24	6 40·5	8 6·8
		16 31·0	18 2·5
	25	2 21·5	3 58·1
		12 12·0	13 53·8
	26	7 52·9	9 45·1
		17 43·4	19 40·8
	27	3 33·9	5 36·4
		13 24·4	15 32·1
	28	9 5·4	1 27·8
		18 55·9	11 23·4
	29	4 46·3	7 14·8
		14 36·8	17 10·4
Mar.	1	10 17·8	3 6·1
		12 3	Sat. III. Sh.
		20 8·3	13 1·8
	2	5 58·8	8 53·1
		12 22	Sat. IV. Sh.
		15 49·3	18 48·8
	3	1 39·8	4 44·5
		11 30·3	14 40·1
	4	7 11·4	10 31·5
		17 1·8	20 27·2
	5	2 52·3	6 22·9
		12 42·9	16 18·6
	6	8 23·9	2 14·2
		18 14·4	12 9·9
	7	4 4·9	8 1·3

1896.	I. (877°·90) h m	II. (870°·27) h m	1896.	I. (877°·90) h m	II. (870°·27) h m
Mar. 7	13 55·4	17 57·0	Mar. 25	14 58·9	12 52·6
8	9 36·4	3 52·7	26	10 40·0	8 44·1
	16 2	Sat. III. Sh.		20 30·6	18 39·8
	19 26·9	13 48·4	27	6 21·2	4 35·6
9	5 17·4	9 39·8		16 11·7	14 31·3
	15 8·0	19 35·4	28	2 2·3	10 22·8
10	10 49·0	5 31·1		11 52·8	20 18·5
	20 39·5	15 26·8	29	7 34·0	6 14·3
11	6 30·0	1 22·5		17 24·5	16 10·0
	16 20·5	11 18·2	30	3 15·1	2 5·7
12	2 11·1	7 9·6		13 5·7	12 1·5
	12 1·6	17 5·3	31	8 46·8	7 53·0
13	7 42·6	3 1·0		18 37·4	17 48·7
	17 33·2	12 56·7	Apr. 1	4 27·9	3 44·5
14	3 23·7	8 48·1		14 18·5	13 40·2
	13 14·2	18 43·8	2	9 59·7	9 31·7
15	8 55·3	4 39·6		19 50·2	19 27·5
	18 45·8	14 35·3	3	5 40·8	5 23·2
	20 2	Sat. III. Sh.		15 31·9	15 19·0
16	4 36·4	10 26·7	4	1 22·0	1 14·8
	14 26·9	20 22·4		11 12·5	11 10·5
17	10 8·0	6 18·1	5	6 53·7	7 2·0
	19 58·5	16 13·8		16 44·3	16 57·8
18	5 49·0	2 9·5	6	2 34·9	2 53·5
	15 39·6	12 5·3		8 1	Sat. III. Sh.
19	6 24	Sat. IV. Sh.		12 25·5	12 49·3
	11 20·7	7 56·7	7	8 6·6	8 40·8
	21 11·2	17 52·4		17 57·2	18 36·6
20	7 1·7	3 48·1	8	3 47 8	4 32·4
	16 52·3	13 43·9		13 38·4	14 28·1
21	2 42·8	9 35·3	9	9 19·6	10 19·7
	12 33·4	19 31·0	10	5 0·7	6 11·2
22	8 14·5	5 26·7		14 51·3	16 7·0
	18 5·0	15 22·5	11	10 32·5	11 58·5
23	3 55·6	1 18·2	12	6 13·7	7 50·1
	13 46·1	11 13·9		16 4·3	17 45·8
24	9 27·3	7 5·4	13	1 54·9	3 41·6
	19 17·8	17 1·1		12 1	Sat. III. Sh.
25	5 8·4	2 56 9		11 45·5	13 37·4

1896.		I. (877°·90) h m	II. (870°·27) h m
Apr.	14	7 26·7	9 28·9
	15	3 7·9	5 20·5
		12 58·5	15 16·3
	16	8 39·7	11 7·8
	17	4 20·9	6 59·4
		14 11·5	16 55·2
	18	9 52·7	12 46·7
	19	5 33·9	8 38·3
		15 24·5	18 34·1
	20	11 5·8	14 25·7
		16 0	Sat. III. Sh.
	21	6 47·0	10 17·2
	22	2 28·2	6 8·8
		12 18·8	16 4·6
	23	8 0·0	11 56·2
	24	3 41·3	7 47·8
		13 31·9	17 43·6
	25	9 13·1	13 35·2
	26	4 54·3	9 26·7
	27	10 26·2	15 14·1
	28	6 7·4	11 5·7
	29	11 39·3	6 57·3
	30	7 20·5	12 44·7
May	1	12 52·4	8 36·3
	2	8 33·6	14 23·8
	3	14 5·5	10 15·4
	4	9 46·8	6 7·0
	5	5 28·0	11 54·4
	6	10 59·9	7 46·0
	7	6 41·2	13 33·5
	8	12 13·1	9 25·1
		12 31	Sat. IV. Sh.
	9	7 54·4	5 16·7
		17 45·0	15 12·5
	10	13 26·3	11 4·2
	11	9 7·5	6 55·8
	12	14 39·5	12 43·2
	13	10 20·7	8 34·9
		6 2·0	14 22·3

1896.		I. (877°·90) h m	II. (870°·27) h m
May	15	11 33·9	10 14·0
	16	7 15·2	16 1·4
	17	12 47·1	11 53·1
	18	8 28·4	7 44·7
	19	7 59	Sat. III. Sh.
		13 0·4	13 32·2
	20	9 41·7	9 23·8
	21	5 22·9	5 15·5
		15 13·6	15 11·3
	22	10 54·9	11 2·9
		15 53	♃'s centre 8″·1 south of * 9ᵐ·0 B.D. 20°·2104 Occultation.
		20 45·5	20 58·8
	23	0 4	♃'s centre 41″·3 south of * 9ᵐ·2 B.D. 20°·2106.
		6 36·2	6 54·6
		16 26·8	16 50·4
	24	12 8·1	12 42·1
	25	6 32	Sat. IV. Sh.
		7 49·4	8 33·7
	26	11 58	Sat. III. Sh.
		13 21·4	14 21·2
	27	9 2·7	10 12·9
	28	14 34·6	16 0·4
	29	10 15·9	11 52·0
	30	5 57·2	7 43·7
	31	11 29·1	13 31·2
June	1	7 10·4	9 22·8
	2	12 42·4	15 10·3
		15 57	Sat. III. Sh.
	3	8 23·7	11 2·0
	4	13 55·7	6 53·7
	5	9 37·0	12 41·2
	6	5 18·3	8 32·8
	7	10 50·3	14 20·3
	8	6 31·6	10 12·0
	9	12 3·6	15 59·5
	10	7 44·9	11 51·2

1896.	I. (877°·90) h m	II. (870°·27) h m	1896.	I. (877°·90) h m	II. (870°·27) h m
June 11	13 16·8	7 42·9	June 14	10 11·4	15 9·6
12	8 58·2	13 30·4	15	5 52·8	11 1·2
13	4 39·5	9 22·0	16	11 24·7	6 52·9
14	9	Occultation of ♃'s system by the Moon—*V.* next paper.	17	7 6·0	12 40·4
			18	12 38·0	8 32·1

The intervals between successive passages of the zero-meridian vary in System I. between $9^h\ 50^m{\cdot}40$ and $50^m{\cdot}66$, and in II. between $9^h\ 55^m{\cdot}58$ and $55^m{\cdot}84$. The differences of successive values of the longitudes of ♃'s Central Meridian for the two-days interval vary in System I. between 1755°·31 and 1756°·10, and in II. between 1740°·05 and 1740°·83.

If, on *Jupiter's* spheroidal surface, ω is the (jovicentrically western) longitude of a spot or marking in the adopted system of longitudes, ω_0 that of the central meridian, and β' the latitude of the spot, the apparent co-ordinates x and y of the spot, referred to the semiaxes a and b of the disc, are:

$$x = a \cos \beta' \sin (\omega - \omega_0)$$
$$y = b \sin (\beta - B') + x \sin B \tan \tfrac{1}{2} (\omega - \omega_0)$$

where $\tan B' = \tan B \sec \varepsilon_0$. The values of ω and β' are, of course, best determined when the spot is crossing the central meridian, so that

$$\omega = \omega_0$$

and

$$\sin (\beta' - B') = \frac{y}{b}.$$

The jovicentric latitude β of the spot is connected with β' by $\tan \beta = \tan \beta' \cos \varepsilon_0$, but it is not needed, as in practice it is sufficient to know β', the jovicentric latitude of the point, where the sphere round the polar axis as diameter is cut by the perpendicular line from the spot upon the polar axis. The latitude B being small, B′ is found by adding to B one fifteenth part.

The occultation of a star $9^m{\cdot}0$ by *Jupiter* on May 22 will be observable in the greater part of North America. Assuming the apparent place of the star to be $\alpha\ 8^h\ 26^m\ 9^s{\cdot}4$, $\delta + 19°\ 55'\ 33''{\cdot}7$, derived from the lately published "Catalog der Astron. Gesellschaft, Zehntes Stück," and referring its apparent position to the axes of *Jupiter's* disc, the star will be in conjunction with the following lighted border of the disc, May 22: $15^h\ 2^m$ Gr., $8''{\cdot}4$ north, and with the preceding limb at $16^h\ 33^m$ Gr., $7''{\cdot}4$ north. The occultation of the star by *Jupiter* takes place, geocentrically, from $15^h\ 8^m$ to $16^h\ 28^m$ Gr. The effect of parallax will be to retard these times some minutes, and to shorten the duration. The disappearance of the star behind the not fully illuminated limb will be visible in North America, except in the western States, where it occurs too near sunset. But observers in the

west may watch the conjunction of the star with Sat. II., which occurs, geocentrically, at $16^h\ 52^m$ Gr., the satellite passing $7''{\cdot}0$ south of the star. The conjunction of the star with Sat. I. occurs earlier in the night, at $11^h\ 40^m$ Gr., the satellite passing $11''{\cdot}0$ south, too late for European, too early for American, observers.

The measurements of the *fifth* satellite, which Prof. Barnard has secured during its third apparition on eight nights (October 8, 29, November 4, 11, 12, 18, 19, December 3, 1894) and which he has kindly communicated before publication, leave the correction required by the ephemeris in No. 3,253 of the *Astron. Nachrichten* rather undecided, so that for the present ephemeris I have made no change in the adopted daily rate of motion $722°{\cdot}633$, which corresponds to a period of $11^h\ 57^m\ 22^s{\cdot}60$. No other measurements made during last season have come to my knowledge.

Ephemeris of the Fifth Satellite of Jupiter, 1895–96.

Greenwich Noon.	P+90°.	a_s	b_s	l_s-L_s	Greenwich Times of greatest Elongations.	
1895.	°	″	″	°	h m	h m
Oct. 21	106·61	47·00	+0·55	185·85	14 45 W.	20 44 E.
23	106·68	47·27	·54	191·04	14 35	20 33
25	106·75	47·55	·53	196·24	14 24	20 23
27	106·81	47·83	·53	201·45	14 14	20 13
29	106·87	48·12	·52	206·67	14 4	20 2
31	106·93	48·41	·51	211·91	13 53 W.	19 52 E.
Nov. 2	106·98	48·70	+0·51	217·15	13 43	19 41
4	107·03	49·00	·50	222·41	13 32	19 31
6	107·07	49·30	·49	227·67	13 22	19 20
8	107·11	49·60	·49	232·95	13 11	19 10
10	107·15	49·90	·48	238·24	13 1 W.	18 59 E.
12	107·18	50·21	+0·48	243·55	18 49 E.	24 47 W.
14	107·20	50·52	·47	248·86	18 38	24 37
16	107·22	50·83	·47	254·19	18 28	24 26
18	107·24	51·14	·46	259·52	18 17	24 16
20	107·26	51·46	·46	264·87	18 6	24 5
22	107·27	51·77	+0·45	270·23	17 56 E.	23 54 W.
24	107·27	52·08	·45	275·61	17 45	23 43
26	107·27	52·39	·45	280·99	17 34	23 33
28	107·27	52·70	·44	286·38	17 23	23 22
30	107·26	53·01	·44	291·79	17 13	23 11
Dec. 2	107·25	53·31	+0·44	297·21	17 2 E.	23 0 W.
4	107·23	53·61	·44	302·63	16 51	22 50
6	107·21	53·91	·43	308·07	16 40	22 39
8	107·19	54·20	·43	313·52	16 29	22 28
10	107·16	54·49	·43	318·98	16 18	22 17

Greenwich Noon.	P+90°.	a_s	b_s	l_s-L.	Greenwich Times of greatest Elongations.	
1895.	°	″	″	°	h m	h m
Dec. 12	107·13	54·77	+0·43	324·44	16 7 E.	22 6 W.
14	107·09	55·05	·43	329·92	15 56	21 55
16	107·05	55·32	·43	335·41	15 46	21 44
18	107·00	55·58	·43	340·90	15 35	21 33
20	106·95	55·83	·43	346·40	15 24	21 22
22	106·90	56·07	+0·43	351·91	15 13 E.	21 11 W.
24	106·84	56·30	·43	357·43	15 2	21 0
26	106·78	56·52	·43	2·95	14 51	20 49
28	106·71	56·73	·43	8·48	14 40	20 38
30	106·64	56·93	·43	14·01	14 29	20 27
1896.						
Jan. 1	106·57	57·11	+0·44	19·55	14 18 E.	20 16 W.
3	106·49	57·28	·44	25·09	14 7	20 5
5	106·42	57·44	·44	30·64	13 55	19 54
7	106·34	57·58	·45	36·18	13 44	19 43
9	106·25	57·71	·45	41·73	13 33	19 32
11	106·16	57·82	+0·45	47·28	13 22 E.	19 21 W.
13	106·08	57·92	·46	52·83	13 11	19 10
15	105·99	58·00	·46	58·38	13 0	18 59
17	105·89	58·06	·46	63·93	12 49	18 48
19	105·80	58·11	·47	69·47	12 38	18 37
21	105·71	58·13	+0·47	75·01	12 27 E.	18 26 W.
23	105·61	58·15	·48	80·55	12 16	18 15
25	105·51	58·14	·48	86·08	12 5	18 4
27	105·42	58·12	·49	91·61	11 54	17 53
29	105·32	58·08	·49	97·13	11 43	17 42
31	105·23	58·02	+0·49	102·64	11 32 E.	17 31 W.
Feb. 2	105·13	57·95	·50	108·15	11 21	17 20
4	105·04	57·86	·50	113·64	11 10	17 9
6	104·94	57·75	·51	119·13	10 59	16 58
8	104·85	57·63	·51	124·60	10 48	16 47
10	104·76	57·49	+0·51	130·07	10 37 E.	16 36 W.
12	104·67	57·34	·52	135·52	10 27	16 25
14	104·59	57·17	·52	140·97	10 16	16 14
16	104·51	56·99	·53	146·40	10 5	16 4
18	104·43	56·80	·53	151·81	9 54	15 53
20	104·35	56·59	+0·53	157 21	9 43 E.	15 42 W.
22	104·28	56·37	·53	162·60	9 33	15 31
24	104·21	56·14	·54	167·98	9 22	15 21
26	104·14	55·90	·54	173·34	9 11	15 10

Greenwich Noon. 1896.	P+90°.	a_s	b_s	l_s-L.	Greenwich Times of greatest Elongations.	
	°	"	"	°	h m	h m
Feb. 28	104·08	55·65	·54	178·69	9 1	14 59
Mar. 1	104·02	55·40	+0·54	184·02	8 50 E.	14 49 W.
3	103·97	55·13	·54	189·33	8 39	14 38
5	103·92	54·85	·54	194·63	8 29	14 28
7	103·87	54·57	·54	199·92	8 18	14 17
9	103·83	54·28	·54	205·19	8 8	14 7
11	103·79	53·99	+0·54	210·44	7 57 E.	13 56 W.
13	103·76	53·69	·54	215·68	7 47	13 46
15	103·74	53·39	·54	220·90	7 37	13 35
17	103·72	53·08	·54	226·11	7 26	13 25
19	103·70	52·77	·54	231·30	7 16	13 15
21	103·69	52·46	+0·54	236·48	7 6 E.	13 4 W.
23	103·68	52·14	·54	241·64	6 55	12 54
25	103·68	51·83	·53	246·79	6 45	12 44
27	103·68	51·51	·53	251·92	6 35	12 33
29	103·69	51·20	·53	257·04	6 25	12 23
31	103·71	50·88	+0·52	262·15	6 14 E.	12 13 W.
Apr. 2	103·73	50·56	·52	267·24	12 3 W.	18 2 E.
4	103·75	50·25	·52	272·31	11 53	17 52
6	103·78	49·93	·51	277·38	11 43	17 42
8	103·81	49·62	·51	282·43	11 33	17 31
10	103·85	49·31	+0·50	287·47	11 23 W.	17 21 E.
12	103·89	49·01	·50	292·49	11 13	17 11
14	103·93	48·70	·49	297·50	11 3	17 1
16	103·98	48·40	·49	302·50	10 53	16 51
18	104·04	48·10	·48	307·50	10 43	16 42
20	104·10	47·80	+0·48	312·49	10 33 W.	16 32 E.
22	104·16	47·51	·47	317·44	10 23	16 22
24	104·22	47·23	·46	322·40	10 13	16 12
26	104·29	46·95	·46	327·35	10 3	16 2
28	104·37	46·67	·45	332·29	9 53	15 52
30	104·44	46·39	+0·44	337·22	9 44 W.	15 42 E.

The differences between successive values of l_s-L for the interval of two days vary between 1444°·93 and 1445°·55. The values are to be interpolated for the times at which the rectangular co-ordinates are measured, when the corresponding computed co-ordinates will be

$$x_s = a_s \sin (l_s - L) \text{ in pos. angle } P + 90°$$
$$y_s = b_s \cos (l_s - L) \quad \text{,,} \quad \text{,,} \quad P.$$

Col. Cooper's Observatory,
Markree, Collooney, Ireland.

Data for computing the Positions of the Satellites of Jupiter, 1895–96. By A. Marth.

The following data for computing the places of the satellites for the present apparition of *Jupiter* are a continuation of those for the four preceding apparitions published in the *Monthly Notices*. They furnish, at intervals of ten days, the mean longitudes l of the satellites and the arguments of their inequalities. The motions of the longitudes and arguments during the intervals, and the inequalities corresponding to the arguments are to be found on pp. 524–539 of vol. li.

The inclinations γ and the longitudes of the nodes Γ of the planes of the orbits referred to the plane of *Jupiter's* equator are the following :—

		Sat. I.		Sat. II.		Sat. III.		Sat. IV.	
		γ_1	$O-\Gamma_1$	γ_2	$O-\Gamma_2$	γ_3	$O-\Gamma_3$	γ_4	$O-\Gamma_4$
1895.		°	°	°	°	°	°	°	°
Aug.	24	0·0099	169·3	0·4832	167·93	0·1256	129·58	0·3389	28·63
Sept.	23	99	170·7	·4830	168·92	·1257	129·78	·3386	28·68
Oct.	23	99	172·1	·4828	169·92	·1258	129·98	·3383	28·75
Nov.	22	99	173·5	·4826	170·91	·1259	130·17	·3381	28·81
Dec.	22	99	174·9	·4825	171·90	·1259	130·35	·3379	28·88
1896									
Jan.	21	0·0099	176·3	0·4823	172·88	0·1260	130·53	0·3378	28·95
Feb.	20	99	177·7	·4821	173·86	·1261	130·71	·3377	29·02
Mar.	21	98	179·0	·4819	174·83	·1262	130·88	·3376	29·09
Apr.	20	98	180·4	·4817	175·80	·1262	131·04	·3376	29·16
May	20	98	181·7	·4816	176·76	·1263	131·20	·3376	29·24
June	19	0·0098	183·0	0·4814	177·71	0·1264	131·35	0·3377	29·32

In a "Note on the Determination of the Planes of the Orbits of *Jupiter's* Satellites," published in vol. xliv. p. 241 ff., it was pointed out that the most promising means for determining the longitudes of the nodes of the orbits with accuracy would be found in micrometrical measurements of the rectangular coordinates of the shadows of the satellites near their midtransits, if these measurements are made about the times when the planes of the orbits pass through the Sun. Though the opportunities of 1884, and at the next nodal passages in 1890, pointed out in vol. l. p. 347, appear to have been neglected, observers ought to be reminded of their opportunities offered during the present apparition of *Jupiter*. The nodal passages occur, indeed, too late in the season to allow corresponding observations to be made on both sides of the centre, and when *Jupiter* becomes accessible again after the conjunction with the Sun, the shadows will cross at greater distances from the centre. After another revolution of *Jupiter*, in 1908, the circumstances will be rather more favourable, but the best opportunities for getting corresponding observations before and after the nodal passages will only present themselves during the oppositions of 1920 and 1932. But, at the opposite node, the most favourable opportunities during *Jupiter's* 83 years' cycle will offer themselves in 1902 and 1914, and,

though *Jupiter* will then have considerable southern declination, it is to be hoped the opportunities will not again be neglected. At present it is unknown what degree of accuracy is attainable in measuring the co-ordinates of the shadows. It would be mere waste of labour to give accurate predictions, but I am willing to compute the measures of the shadows made during the present apparition, if they are published or communicated in time.

The rectangular co-ordinates of the satellites referred to the axes of the disc of *Jupiter* are found by means of the formulæ (*v.* vol. li. p. 506):

$$\Delta' = \Delta + a\rho \cos B \,.\, \cos(v - L)$$

$$x = \frac{a''}{\Delta'} \,.\, \rho \,.\, \sin(v - L)$$

$$y = \frac{a''}{\Delta'} \,.\, \rho \left(\cos(v - L) \sin B + \sin\gamma \cos B \,.\, \sin(v - \Gamma)\right).$$

The values of the distance Δ of *Jupiter* from the Earth and of L and B are to be interpolated for the times t, for which the positions are required, but those of l and of the arguments on which the true longitudes v and the rad. vect. ρ depend, for the times $t - \tau$, if τ is the light-time given in the ephemeris for physical observations.

As there will be an occultation of *Jupiter's* system by the Moon on June 14, I have computed the positions of the satellites and give here the results:

1896 June 14.			Sat. I.		Sat. II.		Sat. III.		Sat. IV.	
			x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4
h	m		″	″	″	″	″	″	″	″
9	0	Gr.	+96·18	+0·03	+124·55	−1·71	+202·68	+0·82	−425·44	−2·81
9	30		96·50	−0·01	121·14	1·71	205·15	0·79	426·01	2·78
10	0		96·29	0·05	117·58	1·72	207·55	0·76	426·55	2·75
10	30		95·54	0·09	113·87	1·72	209·88	0·73	427·07	2·72
11	0		+94·27	−0·13	+110·00	−1·71	+212·15	+0·69	−427·56	−2·70

To convert these co-ordinates into differences of right ascension and declination, we have

$$s \sin(p - P) = x \qquad 15 \cos\delta\,(a - A) = s \sin p$$

$$s \cos(p - P) = y \qquad \delta - D = s \cos p$$

Hence

			$a_1 - A$	$\delta_1 - D$	$a_2 - A$	$\delta_2 - D$	$a_3 - A$	$\delta_3 - A$	$a_4 - A$	$\delta_4 - A$
h	m		s	″	s	″	s	″	s	″
9	0	Gr.	+6·488	−27·89	+8·270	−37·80	+13·688	−58·06	−28·762	+120·82
9	30		6·508	28·03	8·137	36·81	13·854	58·81	28·799	121·03
10	0		6·493	28·02	7·896	35·78	14·015	59·54	28·834	121·22
10	30		6·443	27·84	7·645	34·71	14·171	60·25	28·868	121·40
11	0		+6·356	−27·51	+7·384	−33·58	+14·323	−60·95	−28·901	+121·58

The values of the mean distances of the satellites here assumed are those corresponding to the mass of *Jupiter's* system 1 : 1047·7. If it is preferred to adopt another mass, all these numbers must be multiplied by a factor, the logarithm of which may be inferred from the values in vol. li. p. 516.

First Satellite.

Greenwich Noon.		Longitude. $l_1 - O$	S_1	e_1	Arguments. β_1	γ_1	δ_1	ϵ_1
1895.		°	°					
Aug.	24	99·5680	+·0014	·2296	·807	·033	·677	·197
Sept.	3	334·4575	13	·9026	·226	·681	·330	·222
	13	209·3471	13	·5757	·644	·329	·982	·246
	23	84·2366	12	·2487	·062	·978	·634	·271
Oct.	3	319·1262	11	·9217	·480	·626	·287	·296
	13	194·0158	10	·5947	·899	·274	·939	·320
	23	68·9053	+·0010	·2677	·317	·923	·591	·345
Nov.	2	303·7949	09	·9407	·735	·571	·243	·370
	12	178·6844	08	·6137	·153	·219	·896	·395
	22	53·5740	07	·2867	·572	·868	·548	·419
Dec.	2	288·4636	07	·9598	·990	·516	·200	·444
	12	163·3531	06	·6328	·408	·164	·852	·469
	22	38 2427	+·0005	·3058	·826	·812	·505	·493
1896.								
Jan.	1	273·1322	05	·9788	·245	·461	·157	·518
	11	148·0218	04	·6518	·663	·109	·809	·543
	21	22·9114	03	·3248	·081	·757	·461	·567
	31	257·8009	02	·9978	·499	·406	·114	·592
Feb.	10	132·6905	02	·6708	·918	·054	·766	·617
	20	7·5800	+·0001	·3439	·336	·702	·418	·641
Mar.	1	242·4696	+·0000	·0169	·754	·351	·071	·666
	11	117·3592	−·0000	·6899	·172	·999	·723	·691
	21	352·2487	01	·3629	·591	·647	·375	·715
	31	227·1383	02	·0359	·009	·296	·027	·740
Apr.	10	102·0278	03	·7089	·427	944	·680	·765
	20	336 9174	−·0003	·3819	·845	·592	·332	·790
	30	211·8070	04	·0549	·264	·241	·984	·814
May	10	86·6965	05	·7280	·682	·889	·636	·839
	20	321·5861	06	·4010	·100	·537	·289	·864
	30	196·4756	06	·0740	·518	·186	·941	·888
June	9	71·3652	07	·7470	·937	·834	·593	·913
	19	306·2548	−·0008	·4200	·355	·482	·246	·938
	29	181·1443	08	·0930	·773	·131	·898	·962

Greenwich Noon.	*First Satellite.* Arguments. ζ_1	η_1	θ_1	*Second Satellite.* Longitude. l_2-O	S_2	Arguments. α_2	β_2
1895.				s	°		
Aug. 24	·752	·052	·869	58·2345	−·0089	·61482	·807
Sept. 3	·773	·073	·889	351·9818	89	·45132	·226
13	·795	·094	·910	285·7290	89	·28783	·644
23	·817	·114	·930	219·4763	89	·12433	·062
Oct. 3	·839	·135	·951	153·2235	89	·96084	·480
13	·860	·156	·972	86·9708	89	·79735	·899
23	·882	·177	·992	20·7180	−·0089	·63385	·317
Nov. 2	·904	·197	·013	314·4653	89	·47036	·735
12	·926	·218	·033	248·2125	89	·30687	·153
22	·947	·239	·054	181·9598	89	·14337	·572
Dec. 2	·969	·260	·074	115·7071	89	·97988	·990
12	·991	·280	·095	49·4543	89	·81639	·408
22	·013	·301	·116	343·2016	−·0089	·65289	·826
1896.							
Jan. 1	·034	·322	·136	276·9488	89	·48940	·245
11	·056	·343	·157	210·6961	89	·32590	·663
21	·078	·363	·177	144·4433	89	·16241	·081
31	·100	·384	·198	78·1906	89	·99892	·499
Feb. 10	·121	·405	·219	11·9378	89	·83542	·918
20	·143	·426	·239	305·6851	−·0088	·67193	·336
Mar. 1	·165	·446	·260	239·4324	88	·50844	·754
11	·187	·467	·280	173·1796	88	·34494	·172
21	·208	·488	·301	106·9269	88	·18145	·591
31	·230	·509	·322	40·6741	87	·01796	·009
Apr. 10	·252	·529	·342	334·4214	87	·85446	·427
20	·274	·550	·363	268·1686	−·0087	·69097	·845
30	·295	·571	·383	201·9159	86	·52748	·264
May 10	·317	·591	·404	135·6632	86	·36398	·682
20	·339	·612	·425	69·4104	86	·20049	·100
30	·361	·633	·445	3·1577	85	·03699	·518
June 9	·382	·654	·466	296·9049	85	·87350	·937
19	·404	·674	·486	230·6522	−·0084	·71001	·355
29	·426	·695	·507	164·3994	84	·54651	·773

Second Satellite.

Greenwich Noon.	Arguments. γ_2	δ_2	e_2	ζ_2	η_2	θ_2	ι_2	π_2	λ_2
1895.									
Aug. 24	·863	·563	·746	·752	·552	·369	·697	·667	·483
Sept. 3	·678	·378	·562	·773	·573	·389	·722	·524	·340
13	·493	·194	·378	·795	·594	·410	·746	·382	·198
23	·307	·010	·194	·817	·614	·430	·771	·239	·055
Oct. 3	·122	·826	·010	·839	·635	·451	·796	·096	·912
13	·937	·641	·826	·860	·656	·472	·820	·953	·769
23	·752	·457	·642	·882	·677	·492	·845	·811	·626
Nov. 2	·566	·273	·458	·904	·697	·513	·870	·668	·483
12	·381	·089	·274	·926	·718	·533	·895	·525	·340
22	·196	·904	·089	·947	·739	·554	·919	·382	·197
Dec. 2	·011	·720	·905	·969	·760	·574	·944	·239	·054
12	·826	·536	·721	·991	·780	·595	·969	·097	·911
22	·640	·352	·537	·013	·801	·616	·993	·954	·769
1896.									
Jan. 1	·455	·168	·353	·034	·822	·636	·018	·811	·626
11	·270	·983	·169	·056	·843	·657	·043	·668	·483
21	·085	·799	·985	·078	·863	·677	·067	·526	·340
31	·899	·615	·801	·100	·884	·698	·092	·383	·197
Feb. 10	·714	·431	·617	·121	·905	·719	·117	·240	·054
20	·529	·246	·433	·143	·926	·739	·141	·097	·911
Mar. 1	·344	·362	·249	·165	·946	·760	·166	·955	·768
11	·158	·878	·064	·187	·967	·780	·191	·812	·625
21	·973	·694	·880	·208	·988	·801	·215	·669	·483
31	·788	·509	·696	·230	·009	·822	·240	·526	·340
Apr. 10	·603	·325	·512	·252	·029	·842	·265	·384	·197
20	·417	·141	·328	·274	·050	·863	·290	·241	·054
30	·232	·957	·144	·295	·071	·883	·314	·098	·911
May 10	·047	·772	·960	·317	·091	·904	·339	·955	·768
20	·862	·588	·776	·339	·112	·925	·364	·813	·625
30	·676	·404	·592	·361	·133	·945	·388	·670	·482
June 9	·491	·220	·408	·382	·154	·966	·413	·527	·339
19	·306	·036	·224	·404	·174	·986	·438	·384	·196
29	·121	·851	·039	·426	·195	·007	·462	·242	·054

Third Satellite.

Greenwich Noon.		Longitude. $l_3 - O$	S_3	Arguments. α_3	β_3	γ_3	δ_3	ϵ_3
1895.		°	°					
Aug.	24	307·5678	−·0116	·2552	·4389	·8074	·352	·860
Sept.	3	90·7439	·0116	·6527	·8365	·2257	·150	·299
	13	233·9200	·0116	·0502	·2342	·6439	·949	·738
	23	17·0961	·0115	·4477	·6318	·0622	·747	·177
Oct.	3	160·2722	·0115	·8453	·0295	·4804	·546	·616
	13	303·4483	·0115	·2428	·4272	·8987	·344	·055
	23	86·6244	−·0115	·6403	·8248	·3169	·143	·494
Nov.	2	229·8005	·0115	·0378	·2225	·7352	·941	·933
	12	12·9766	·0114	·4353	·6201	·1534	·740	·372
	22	156·1527	·0114	·8328	·0179	·5717	·538	·811
Dec.	2	299·3288	·0114	·2303	·4154	·9899	·337	·250
	12	82·5049	·0114	·6278	·8131	·4082	·135	·689
	22	225·6810	−·0113	·0253	·2108	·8264	·933	·128
1896.								
Jan.	1	8·8571	·0113	·4229	·6084	·2447	·732	·567
	11	152·0332	·0112	·8204	·0061	·6630	·531	·006
	21	295·2093	·0112	·2179	·4037	·0812	·329	·445
	31	78·3854	·0111	·6154	·8014	·4995	·128	·884
Feb.	10	221·5615	·0111	·0129	·1990	·9177	·926	·323
	20	4·7376	−·0110	·4104	·5967	·3360	·725	·762
Mar.	1	147·9137	·0110	·8079	·9944	·7542	·524	·201
	11	291·0898	·0109	·2054	·3920	·1725	·322	·640
	21	74·2659	·0109	·6029	·7897	·5907	·121	·079
	31	217·4421	·0108	·0005	·1873	·0090	·919	·517
Apr.	10	0·6182	·0107	·3980	·5850	·4272	·718	·956
	20	143·7943	−·0107	·7955	·9826	·8455	·516	·395
	30	286·9704	·0106	·1930	·3803	·2637	·315	·834
May	10	70·1465	·0105	·5905	·7780	·6820	·113	·273
	20	213·3226	·0105	·9880	·1756	·1002	·912	·712
	30	356·4987	·0104	·3855	·5733	·5185	·710	·151
June	9	139·6748	·0103	·7830	·9709	·9368	·509	·590
	19	282·8509	−·0102	·1805	·3686	·3550	·307	·029
	29	66·0270	·0101	·5781	·7662	·7733	·106	·468

Greenwich Noon.		*Third Satellite.* Arguments. ζ_3	η_3	θ_3	ι_3	*Fourth Satellite.* Longitude. l_4-O	B_4	Arg. ω_4
1895.						°	°	
Aug.	24	·752	·052	·869	·056	0·9428	−·0359	·58714
Sept.	3	·773	·073	·889	·452	216·6536	·0359	·18628
	13	·795	·094	·910	·849	72·3643	·0358	·78542
	23	·817	·114	·930	·245	288·0751	·0358	·38457
Oct.	3	·839	·135	·951	·642	143·7858	·0357	·98371
	13	·860	·156	·972	·038	359·4965	·0357	·58285
	23	·882	·177	·992	·435	215·2073	−·0356	·18199
Nov.	2	·904	·197	·013	·831	70·9180	·0356	·78113
	12	·926	·218	·033	·228	286·6288	·0355	·38028
	22	·947	·239	·054	·624	142·3395	·0354	·97942
Dec.	2	·969	·260	·074	·021	358·0502	·0353	·57856
	12	·991	·280	·095	·417	213·7610	·0352	·17770
	22	·013	·301	·116	·814	69·4717	−·0351	·77684
1896.								
Jan.	1	·034	·322	·136	·210	285·1825	·0350	·37599
	11	·056	·343	·157	·607	140·8932	·0349	·97513
	21	·078	·363	·177	·003	356·6039	·0348	·57427
	31	·100	·384	·198	·400	212·3147	·0346	·17341
Feb.	10	·121	·405	·219	·796	68·0254	·0345	·77255
	20	·143	·426	·239	·193	283·7362	−·0344	·37170
Mar.	1	·165	·446	·260	·589	139·4469	·0342	·97084
	11	·187	·467	·280	·986	355·1576	·0341	·56998
	21	·208	·488	·301	·382	210·8684	·0339	·16912
	31	·230	·509	·322	·779	66·5791	·0337	·76826
Apr.	10	·252	·529	·342	·175	282·2899	·0336	·36741
	20	·274	·550	·363	·572	138·0006	−·0334	·96655
	30	·295	·571	·383	·968	353·7113	·0332	·56569
May	10	·317	·591	·404	·365	209·4221	·0330	·16483
	20	·339	·612	·425	·761	65·1328	·0328	·76397
	30	·361	·633	·445	·158	280·8436	·0326	·36312
June	9	·382	·654	·466	·554	136·5543	·0324	·96226
	19	·404	·674	·486	·951	352·2650	−·0322	·56140
	29	·426	·695	·507	·347	207·9758	·0320	·16054

Fourth Satellite.

	Arguments.						
1895.	β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	θ_4
Aug. 24	·352	·903	·581	·168	·265	·159	·948
Sept. 3	·150	·502	·175	·362	·464	·376	·148
13	·949	·101	·770	·555	·663	·593	·347
23	·747	·700	·365	·749	·863	·809	·547
Oct. 3	·546	·299	·959	·943	·062	·026	·746
13	·344	·898	·554	·137	·261	·243	·946
23	·143	·497	·148	·330	·461	·460	·145
Nov. 2	·941	·096	·743	·524	·660	·677	·345
12	·740	·695	·338	·719	·860	·893	·544
22	·538	·294	·932	·912	·059	·110	·744
Dec. 2	·337	·893	·527	·106	·258	·327	·943
12	·135	·492	·122	·299	·458	·544	·143
22	·933	·091	·716	·493	·657	·760	·342
1896.							
Jan. 1	·732	·690	·311	·686	·856	·977	·542
11	·531	·289	·906	·881	·056	·194	·742
21	·329	·888	·500	·074	·255	·411	·941
31	·128	·487	·095	·268	·455	·627	·141
Feb. 10	·926	·086	·689	·462	·654	·844	·340
20	·725	·685	·284	·656	·853	·061	·540
Mar. 1	·524	·284	·879	·850	·053	·278	·739
11	·322	·883	·473	·043	·252	·495	·939
21	·121	·482	·068	·237	·451	·711	·138
31	·919	·081	·663	·431	·651	·928	·338
Apr. 10	·718	·680	·257	·625	·850	·145	·537
20	·516	·279	·852	·818	·050	·362	·737
30	·315	·878	·446	·012	·249	·578	·936
May 10	·113	·477	·041	·206	·448	·795	·136
20	·912	·076	·636	·400	·648	·012	·335
30	·710	·675	·230	·594	·847	·229	·535
June 9	·509	·274	·825	·787	·046	·445	·734
19	·307	·873	·420	·981	·246	·662	·934
29	·106	·472	·609	·175	·445	·879	·133

Errata in Mr. Innes's Paper.

Page 313, 2nd last line, *after* stars *add* near.
„ 314, 9th line, *delete* The brightest star in finder S. of η Pavonis.
„ 314, 19th line, *delete* full stop after "it."
„ 315, 12th line, *for* 71″ *read* > 1″.

Errata in Mr. Knobel's Paper.

Page 434, *for* Batina *read* Batiya.
„ 437, *delete* last sentence of note to Star 61.

INDEX.

PAGE

Abney, Capt. W. de W., address, delivered on presenting the gold medal to Dr. Isaac Roberts 271
Al Achsasi Al Mouakket, on a catalogue of stars in the Calendarium of, E. B. Knobel 429
——————————errata 544
Assets and present property of the Society, 1895 January 1 179
Associates elected 1
Astrographic Chart, measures of plates for the, W. H. M. Christie and F. W. Dyson 60
——————— on the measurement and reduction of plates for the, H. H. Turner 102
——————— Council note on the 255
Astronomy, notes on the progress of, during the year 1894:—
Discovery of minor planets 232
Comets of 1894 233
Progress of meteoric astronomy 236
Total solar eclipses 239
Solar activity in 1894 ..... *ib.*
—— spectroscopy 240
The effective temperature of the Sun 242
The transit of *Mercury* 243
The German heliometer observations of the transits of *Venus*, 1874 and 1882 ..... *ib.*
The recent opposition of *Mars* 244
Jupiter 245
The satellite of *Neptune* 246
Double stars 247
Nova *Normæ* 249
Lockyer's photographic spectra of some of the brighter stars 250
The spectra of *β Lyræ* and *δ Cephei* ..... *ib.*
Star catalogues 252
Spectroscopic observations of nebulæ 253
The Potsdam photometry 255
The Astrographic Chart ..... *ib.*
Astronomical photography 256
Variation of latitude 257
New observatories ..... *ib.*
Atmospheric dispersion, on the effect of, on the position of a star, A. A. Rambaut 123
Auditors' report on the Treasurer's accounts for 1894 178

Barnard, E. E., micrometrical measures of the ball and ring system of the planet *Saturn*, and measures of the diameter of his satellite *Titan*, made with the 36-inch equatorial of the Lick Observatory 367
——————————————— correction 493

PAGE

Barnard, E. E., filar micrometer measures of the diameters of the four bright satellites of *Jupiter*, made with the 36-inch equatorial of the Lick Observatory 382
——— on the variable nebulæ of Hind (N.G.C. 1555) and Struve (N.G.C. 1554) in *Taurus*, and on the nebulous condition of the variable star T *Tauri* 442
——— on a great photographic nebula in *Scorpio*, near *Antares* 453
——— on a photographic study of the earth-lit portion of the new Moon 456
Bosanquet, R. H. M., on a fixed system of star co-ordinates 480
——— on the relation between precession and proper motion 481
Brooks, W. R., on a modified form of Cassegrain telescope..... 324
Brown, E. W., note on the lunar theory 3
Bryant, W. W., *Pallas* and *Vesta* in 1895..... 343
Bulletin Astronomique, answer to an inquiry in, E. J. Stone 346
Burton-Brown, Col. A., notes on suitable stations in Norway for viewing the total eclipse of the Sun on 1896 August 8 93

Candidates proposed..... 1. 51, 85, 279, 323, 345, 407
Cape Catalogue, 1880, comparison of star places of, with the places of the same stars observed at Sydney Observatory, H. P. Hollis . 71
——— a systematic comparison between the places of stars in the, and the Radcliffe Catalogue for 1890, E. J. Stone 292
Cape of Good Hope, Royal Observatory, note on the latitude of, D. Gill 34
Cassegrain telescope, on a modified form of, A. A. Common 86
——— W. R. Brooks 324
——— the brachy telescope of Fritsch and Forster..... 325
Christie, W. H. M., and F. W. Dyson, account of the measurement of a set of four astrographic plates, made at the Royal Observatory, Greenwich..... 60
Collimators, note on observations for coincidence of, in flexure determinations with Greenwich transit circle 327
Comets:—
I. 1888 (Sawerthal; IV. 1889 (Davidson); II. 1891 (Wolf); III. 1892 (Holmes); II. 1893 (Rordame Quénisset), observed at the Radcliffe Observatory, Oxford..... 161
II. 1894 (Gale), observed at the Liverpool Observatory, W. E. Plummer 45
(Encke's), observed at the Royal Observatory, Greenwich..... 159, 320
——— observed at the Radcliffe Observatory, Oxford 162
Comets of 1894, Council note on the 233
Common, A. A., preliminary note on a modified (oblique) form of Cassegrain telescope 86
——— the brachy telescope of Messrs. Fritsch and Forster, of Vienna 325
Cooke, W. E., an apparatus for mechanically calculating star-corrections 288
——— note on Mr. Cooke's paper, H. H. Turner..... 290
——— description of a mechanical apparatus for computing refractions..... 515

Davies, Rev. C. D. P., note on a suggested form of equatorial mounting for a (modified) Newtonian reflector 400
Denning, W. F., observations of *Jupiter* 475
Downing, A. M. W., comparison of the Sun's longitudes for 1900, computed from Newcomb's Tables of the Sun, with those computed from Le Verrier's Tables..... 514
Dreyer, J. L. E., observation of the partial solar eclipse of 1895 March 25 at the Armagh Observatory 338

PAGE

Dyson, F. W., and W. H. M. Christie, measurement of astrographic plates made at the Royal Observatory, Greenwich 60

Eddie, L. A., observations of the transit of *Mercury*, 1894 Nov. 10, made at Grahamstown, Cape of Good Hope 80
Equatorial mounting, suggested form of, for a (modified) Newtonian reflector, Rev. C. D. P. Davies 400
Errata 172, 521, 544
Everett, Alice, note on the binary ι *Leonis* 440

Fellows elected..... 1, 51, 85, 174, 279, 345, 407
Finlay, W. H., on the computation of star-corrections 15

Gale, W. F., the transit of *Mercury*, 1894 November 10..... 315
Gill, D., note on the latitude of the Royal Observatory, Cape of Good Hope 34
Gledhill, J., observations of the phenomena of *Jupiter's* satellites, and of the transits of the red spot, dark and bright spots, &c., at Bermerside Observatory, Halifax, 1894–95 391
Greenwich, Royal Observatory:—
——— measurement of astrographic plates made at the, W. H. M. Christie and F. W. Dyson 60
——— mean areas and heliographic latitudes of Sun-spots in the year 1892, deduced from photographs taken at the, &c. 150
——— observations of occultations of stars by the Moon, and of phenomena of *Jupiter's* satellites, made in the year 1894 154
——— observations of Encke's Comet 159
——— observations of Encke's Comet 320
——— note on the observations for coincidence of the collimators in flexure determinations with the transit circle 327
——— observations of occultations of stars during the total eclipse of the Moon on 1895 March 10 329
——— diameters of *Jupiter* and his satellites ... 477
Greenwich Ten-year Catalogue, 1880, compared with the Pulkowa Catalogue, 1885, W. G. Thackeray 25
——— Five-year Catalogue, 1890, compared with the Radcliffe Catalogue, 1890, E. J. Stone 21
——— compared with the Pulkowa Catalogue, 1885, W. G. Thackeray 25

Hills, Capt. E. H., preliminary note on the determination of terrestrial longitudes by photography 89
Hollis, H. P., comparison of some places of stars observed at the Sydney Observatory with the places of the same stars as given in the Cape Catalogue, 1880 71
Hornsby's observations made at Oxford, mean N.P.D. of γ *Draconis* determined from, E. J. Stone 409
Howlett, Rev. F., remarks on three volumes of Sun-spot drawings presented to the Society 73

Innes, R. T. A., a list of probably new double stars 312
——— errata 544
——— occultation of *Antares*, 1894 October 31 343
Instruments belonging to the Society 182

Johnson, Rev. S. J., the late transit of *Mercury* [1894 November 10] ... 80
Jupiter, Council note on 245

PAGE

Jupiter, observations of the vertical diameter of, T. J. Moore 306
——— transits of spots on, 1894, J. Gledhill 395
——— observations of, W. F. Denning..... 475
——— ephemeris for physical observations of 1895-96, A. Marth... 486, 522
——— and his satellites, diameters of, observed at the Royal Observatory, Greenwich 477
——— and 1 *Geminorum*, equatorial comparisons of, J. Tebbutt 341
Jupiter's fifth satellite, ephemeris for, A. Marth..... 533
——— satellites, phenomena of, 1894, observed at the Royal Observatory, Greenwich 156
——— 1894-95, observed at Bermerside Observatory, Halifax, J. Gledhill 391
——— 1895, observed at Windsor, New South Wales, J. Tebbutt 517
——— filar micrometer measures of, made with the 36-inch equatorial of the Lick Observatory, E. E. Barnard 382
——— data for computing the positions of, 1895-96, A. Marth 536

Keeler, J. E., photographs of the spectrum of the ball and rings of *Saturn* 474
Kepler's equation, a general method for facilitating the solution of, by mechanical means, T. J. J. See 425
Knobel, E. B., on a catalogue of stars in the Calendarium of Mohammad Al Achsasi Al Mouakket..... 429
——— errata 544

Latitude, variation of, Council note on 257
Lewis, T., note on the binary star κ *Pegasi* (β 989)..... 17
——— on the orbit of η *Cassiopeiæ* (Σ 60) 19, 341
Lindemann, A. F., observations of the transit of *Mercury*, 1894 November 10, at Sidmouth, Devon 78
Liverpool Observatory, preliminary note on the position of, W. E. Plummer 37
Longitudes, terrestrial, determinations of, by photography, Captain E. H. Hills 89
Lunar Theory:—
Note on Mr. Stone's theory of the measure of time, S. Newcomb ... 3
Note on the lunar theory, E. W. Brown ..... *ib.*
Re-determination of the Epoch correction and mean motion for Hansen's Lunar Tables, from meridian observations of the Moon, 1750-1892, E. J. Stone 52
Note on Professor Newcomb's note on Mr. Stone's theory of the measure of time, E. J. Stone 146
Lynn, W. T., on the proper motions of three stars in *Ophiuchus*..... 69
——— on the proper motion of the star BAC, 793 302
——— on the proper motion of the star *Cephei* 24 (Hev.) 304
——— note on the proper motion of *Arcturus* 438

Markwick, Lieut.-Col. E. E., notes on the variable stars X and W *Sagittarii* 338
Mars, opposition of, Council note on the 244
——— a negative optical proof of the absence of seas in, H. D. Taylor 462
——— inner satellite of (*Phobos*), micrometer measures of, H. F. Newall 348
Marth, A., ephemerides of the five inner satellites of *Saturn*, 1895 164
——— ephemeris for physical observations of *Jupiter*, 1895-96 486, 522
——— ephemeris of the fifth satellite of *Jupiter* 533
——— data for computing the positions of the satellites of *Jupiter*, 1895-96..... 536
Medal, award of the 187

PAGE

Medal, Address delivered by the President on presenting the, to Dr. Isaac Roberts 271
Mercury, transit of, 1894 November 10, observed at Sidmouth, Devon, A. F. Lindemann 78
——— observed by Rev. S. J. Johnson 80
——— at Grahamstown, Cape of Good Hope, L. A. Eddie... *ib.*
——— by Lieut. B. Taylor 82
——— in New South Wales, H. C. Russell 148
——— W. F. Gale 315
——— in Queensland, J. R. Thomson 316
——— Council note on the 243
Meridian observation, on the need and usefulness of co-operation in, T. H. Safford..... 119
Meteoric astronomy, Council note on the progress of, 1894 236
Minor planets, Council note on the discovery of, 1894..... 232
——— observations of, made with the 15-inch equatorial of the National Mexican Observatory, Tacubaya, F. Valle..... 404
——— *Pallas* and *Vesta* in 1895, W. W. Bryant 343
Moon, new, on a photographic study of the earthlit portion of the, E. E. Barnard 456
——— total eclipse of, 1895 March 10, observations made at the Royal Observatory, Greenwich 329
——— at the Radcliffe Observatory, Oxford 333
——— with the Newall Telescope, Cambridge 334
——— observed at Harrow. Col. G. L. Tupman 336
——— photographs of, G. J. Newbegin ... . *ib.*
Moore, T. J., Observations of the vertical diameter of the planet *Jupiter* 306

Nebulæ, spectroscopic observations of, Council note on 253
Nebulæ and Clusters :—
Photographs of the nebulæ ♃ I. 84 ; *h* 1,442, and ♃ II. 344 *Comæ Berenicis*, I. Roberts 12
Photograph of the nebulæ ♃ I. 143 and II. 536 *Virginis*, I. Roberts 13
Photograph of the nebula near 15 *Monocerotis*, I. Roberts 398
Photograph of the crab nebula M I. *Tauri*, I. Roberts 399
On the variable nebulæ of Hind and Struve in *Taurus*, and on the nebulous condition of the variable star T *Tauri*, E. E. Barnard..... 442
On a great photographic nebula in *Scorpio*, near *Antares*, E. E. Barnard 453
Council note on spectroscopic observations of 253
Neptune's satellite, Council note on H. Struve's researches on 246
Newall, H. F., note on the total eclipse of the Moon, 1895 March 10 ... 334
——— micrometer measurements of *Phobos*, the inner satellite of *Mars*, during the opposition of 1894..... 348
Newbegin, G. J., total eclipse of the Moon, 1895 March 10 336
——— solar eclipse, 1895 March 25... 337
Newcomb, S., note on Mr. Stone's theory of the measure of time 3
——— note on the above paper, E. J. Stone 146
Newtonian reflector, suggested form of equatorial mounting for a modified, Rev. C. D. P. Davies 400
Nova *Aurigæ*, estimations of magnitude of, made at the Radcliffe Observatory, Oxford 164
Nova *Normæ*, Council note on..... 249

Obituary : List of Fellows deceased 188
Allnutt, J. W. F. ..... *ib.*
Carpmael, Charles..... 189

PAGE

Obituary: List of Fellows deceased (*continued*):—
Clark, Edwin 190
Cockle, Sir James 192
Harrison, A. S. 193
Hopkins, B. J. ..... *ib.*
Johnson, Richard 194
Knott, George 195
Leigh, James 197
Morgan, John 198
Ranyard, A. C. ..... *ib.*
Roe, Henry 201
Tomlinson, William ..... *ib.*
Wall, George 202
Observatories, reports of proceedings at, during 1894:—
Greenwich, Royal 203
Edinburgh, Royal 208
Cape of Good Hope, Royal 209
Armagh 213
Cambridge ..... *ib.*
——— (Newall Telescope) 214
Dunsink 215
Glasgow 217
Liverpool 218
Oxford, Radcliffe ..... *ib.*
——— University 219
Rugby 220
Stonyhurst College 221
Dr. Common's, Ealing ..... *ib.*
Mr. Crossley's, Bermerside, Halifax ..... *ib.*
Mr. Espin's (Wolsingham) ..... *ib.*
Dr. Huggins', Upper Tulse Hill 222
Mr. Peek's, Rousdon 223
Dr. Roberts's, Crowborough ..... *ib.*
Mr. Wilson's, Streete, Westmeath 225
Hong Kong ..... *ib.*
Madras 226
Melbourne ..... *ib.*
Sydney 227
Mr. Tebbutt's, Windsor, New South Wales 230
Observatories, new, Council note on 257
Oxford, Radcliffe Observatory, observations of comets Sawerthal, 1888; Davidson, 1889: Wolf, 1891; Holmes, 1892; Rordamo-Quénisset, 1893; and Encke, 1894 161
——— estimations of magnitude of Nova *Aurigæ* 164
——— observations of occultations of stars during the total lunar eclipse of 1895 March 10 333

Photographs, astronomical, announcement respecting the reproduction of 408
Photography, astronomical, Council note on 256
Pleiades, angular distance of two stars in the, suitable for determining the value of a micrometer screw, H. H. Turner 419
Plummer, W. E., preliminary note on the position of the Liverpool Observatory 37
——— observations of Comet II. 1894 (Gale) 45
Potsdam photometry, Council note on 255
Precession and proper motion, on the relation between, R. H. M. Bosanquet 481
Presents announced 2, 52, 86, 279, 323, 345, 408
Progress and present state of the Society 175
Publications of the Society, stock of 180
——— (Memoirs, vol. li.) 187

PAGE

Pulkowa Catalogue, 1885, comparison of, with the Greenwich Ten-year, 1880, and Five-year, 1890, Catalogues, W. G. Thackeray 25
Radcliffe Catalogue, 1890, comparison of the results of, with those contained in the Greenwich Five-year Catalogue, 1890, E. J. Stone 21
——————— a systematic comparison of the places of stars in the, and the Cape Catalogue for 1880, E. J. Stone 292
Rambaut, A.A., on the effect of atmospheric dispersion on the position of a star..... 123
——————— partial eclipse of the Sun, 1895 March 25 337
Refractions, description of a mechanical apparatus for computing, W. E. Cooke 515
Report of the Council to the Seventy-fifth Annual General Meeting of the Society..... 175
List of papers read from March 1894 to January 1895 260
List of donors to the Library, &c. 266
List of Officers and Council..... 277
Roberts, I., photographs of the nebulæ H I. 84; *h* 1442, and H II. 344 *Comæ Berenicis* 12
——————— photograph of the nebulæ H I. 143 and II. 536 *Virginis* ... 13
——————— photograph of the nebula near 15 *Monocerotis*..... 398
——————— photograph of the crab nebula M I. *Tauri* 399
Russell, H. C., the transit of *Mercury*, 1894 November 10, observed in New South Wales..... 148

Safford, T. H., on the need and usefulness of co-operation in Meridian observation 119
——————— on the accuracy of late catalogues of declination of standard stars 495
Sampson, R. A., on the rotation and mechanical state of the Sun (abstract) 280
Saturn, rotation of, in 1894, A. S. Williams..... 354
——— micrometrical measures of the ball and ring system of, and measures of the diameter of his satellite *Titan*, E. E. Barnard 367
——————— correction 493
——— photographs of the spectrum of the ball and rings of, J. E. Keeler 474
——— and *κ Virginis*, results of micrometer comparisons of, J. Tebbutt 519
——— satellites of, ephemerides of the five inner, A. Marth..... 164
See, T. J. J., a general method for facilitating the solution of Kepler's equation by mechanical means 425
Sidgreaves, Rev. W., notes on solar observations at Stonyhurst College Observatory 6
——————— the Wilsonian theory and the Stonyhurst drawings of Sun-spots 282
Smith, C. Michie, the annular eclipse of the Sun, 1894 April 6..... 76
——— the solar eclipse of 1894 Sept. 29 77
Solar activity in 1894, Council note on 239
Solar observations at Stonyhurst Observatory, notes on, W. Sidgreaves. 6
Solar spectroscopy, Council note on 240
Star Catalogues, Council note on 252
Star co-ordinates, on a fixed system of, R. H. M. Bosanquet..... 480
Star-corrections, on the computation of, W. H. Finlay 15
——————— an apparatus for mechanically calculating, W. E. Cooke 288
——————— Note on the above paper, H. H. Turner 290
Stars, double:—
Note on the orbit of *κ Pegasi* (β 989), T. Lewis 17
On the orbit of *η Cassiopeiæ* (Σ 60), T. Lewis 19, 341
Results of measures of, at Windsor, New South Wales, J. Tebbutt 308
A list of probably new, R. T. A. Innes..... 312
——————— errata..... 544

PAGE

Stars, double (*continued*):—
Note on the binary ι *Leonis*, A. Everett 440
Council note on double stars 247
Stars, occultations of, by the Moon, observed at the Royal Observatory, Greenwich, in the year 1894 154
——— during the total eclipse of 1895 March 10, observed at the Royal Observatory, Greenwich 329
——— observed at the Radcliffe Observatory, Oxford 333
——— observed with the Newall Telescope, Cambridge 334
——— observed at Harrow, Col. G. L. Tupman 336
—— daylight occultation of *Antares*, 1894 October 31, observed at Windsor, New South Wales, J. Tebbutt 83
——— R. T. A. Innes 343
Stars, proper motions of:—
Proper motions of three stars in *Ophiuchus*, W. T. Lynn 69
——— of the star B.A.C. 793, W. T. Lynn 302
——— *Cephei* 24 (Hev.), W. T. Lynn 304
——— *Arcturus*, W. T. Lynn 438
Stars, southern close polar, mean places of, E. J. Stone 299
Stars, spectra of:—
Council note on Professor Lockyer's researches 250
——— the spectra of β *Lyræ* and δ *Cephei* ..... *ib.*
Stars, standard, on the accuracy of late catalogues of declination of, T. H. Safford 495
Stars, variable, notes on X and W *Sagittarii*, Col. E. E. Markwick 338
Stone, E. J., note on his theory of the measure of time, S. Newcomb ... 3
——— note on Professor Newcomb's note 146
——— a comparison between the results of the Radcliffe Catalogue of stars, 1890, and the Greenwich Results, 1887–91, contained in the Greenwich Five-year Catalogue, 1890 21
——— a re-determination of the epoch correction and mean motion for Hansen's Lunar Tables from meridian observations of the Moon, 1750–1892 52
——— a systematic comparison of the places of stars given in the Cape Catalogue for 1880 and the Radcliffe Catalogue for 1890 292
——— on the mean places of eight southern close polar stars 299
——— answer to an inquiry in the *Bulletin Astronomique* for May 1895 346
——— a determination of the mean N.P.D., 1790 January 0, of γ *Draconis*, from observations made at Oxford by Dr. Hornsby 409
Struve, H., Council note on his researches on the satellite of *Neptune* ... 246
Sun, annular eclipse of, 1894 April 6, observed at Madras, C. Michie Smith 76
—— solar eclipse of, 1894 September 29, observed at Madras, C. Michie Smith 77
——— observed from the SS. 'Yarrawonga,' H. G. Thomas 78
——— 1895, March 25, G. J. Newbegin 337
——— A. A. Rambaut ..... *ib.*
——— J. L. E. Dreyer 338
—— eclipse of, on 1896 August 8, notes on suitable stations for observations in Norway, Col. Burton-Brown 93
—— Council note on total eclipses of 239
—— longitudes of, for 1900, from Newcomb's and Le Verrier's Tables, A. M. W. Downing 514
—— effective temperature of, Council note on the 242
—— rotation and mechanical state of the, R. A. Sampson (abstract) ... 280

PAGE

Sun-spot drawings, remarks on three volumes of, presented to the Society, Rev. F. Howlett 73
Sun-spots, mean areas and heliographic latitudes of, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius 150
———— the Wilsonian theory and the Stonyhurst drawings of, Rev. W. Sidgreaves 282
———— the thermal radiation from, W. E. Wilson 457
Sydney Observatory, places of stars observed at, compared with those given in the Cape Catalogue, 1880, H. P. Hollis 71

Taylor, Lieut. B., observations of the transit of *Mercury*, 1894 Nov. 10 82
Taylor, H. D., a negative optical proof of the absence of seas in *Mars*... 462
Tebbutt, J., result of micrometer comparisons of *Uranus* and *a Libræ*, 1894 October 5 83
———— Observation of a daylight occultation of *Antares*, 1894 October 31 ..... *ib.*
———— results of double star measures with the 8-inch equatorial at Windsor, New South Wales, in the year 1894..... 308
———— equatorial comparisons of *Jupiter* and 1 *Geminorum*, 1895 January 5 and 10..... 341
———— observations of the phenomena of *Jupiter's* satellites with the 8-inch equatorial at Windsor, New South Wales, in the year 1895 517
———— results of micrometer comparisons of *Saturn* and *κ Virginis* 519
Thackeray, W. G., comparison of the Pulkowa Catalogue, 1885, with the Greenwich Ten-year, 1880, and Five-year, 1890, Catalogues... 25
Thomas, H. G., observation of the solar eclipse, 1894 September 29 ... 78
Thomson, J. P., the transit of *Mercury*, 1894 November 11: egress ... 316
Treasurer's account for 1894 176
Trust Funds 178
Tupman, Col. G. L., occultations observed at Harrow during the total eclipse of the Moon, 1895 March 10 336
Turner, H. H., on the measurement and reduction of the plates for the astrographic chart 102
———— note on Mr. Cooke's paper on an apparatus for mechanically calculating star-corrections 290
———— on the angular distance of two stars in the *Pleiades* suitable for determining the value of a micrometer screw..... 419

Uranus, conjunction of, with *a Libræ*, 1894 October 5, observed by J. Tebbutt 83

Valle, F., observations of minor planets made with the 15-inch equatorial of the National Mexican Observatory, Tacubaya..... 404
Venus, transits of, 1874 and 1882, Council note on the German heliometer observations of the 243

Williams, A. Stanley, on the rotation of *Saturn* in 1894 354
Wilson, W. E., the thermal radiation from Sun-spots; observations at Daramona, Streete, co. Westmeath..... 457

LIST OF PRESENTS

RECEIVED DURING THE SESSION OF 1894-95,

AND OF

BOOKS PURCHASED WITH THE TURNOR AND HORROX FUND

DURING THE SAME PERIOD,

FORMING

APPENDIX XI.

To the Catalogue of the Library of the Royal Astronomical Society.

American Academy of Arts and Sciences, Proceedings, vol. xx., xxi., 8vo. *Boston*, 1893–94	The Academy.
American Journal of Mathematics, vol. xvi. 3–xvii. 2, 4to. *Baltimore*, 1894–95	The Editors.
American Journal of Science, series III., Nos. 283–294, 8vo. *New Haven*, 1894–95	——
Amsterdam, Koninklijke Akademie van Wetenschappen, Jaarboek, 1893, 8vo. *Amsterdam*, 1893	The Academy.
—— Verhandelingen, 1ste sectie, Deel ii., Nos. 1–6, 8, 8vo. *Amsterdam*, 1893–94	——
—— Verslagen der Zittingen, 1893–94, 8vo. *Amsterdam*, 1894	——
Angelitti, F., Determinazioni assolute della declinazione magnetica nel R. Osservatorio di Capodimonte eseguite nell' anno 1891, 4to. *Napoli*, 1893	The Author.
—— Variazioni della declinazione magnetica osservate nella R. Specola di Capodimonte nell' anno 1891, 4to. *Napoli*, 1894	——
—— Distanze zenitale circummeridiane del Sole osservate nell' anno 1821 dall' astronomo Carlo Brioschi, 4to. *Napoli*, 1894	——

The Author. Armani, P., Francesco Denza, Cenni necrologici, 8vo. *Roma*, 1894

The Association. Association Géodésique Internationale, Comptes rendus des séances de la Commission Permanente réunie à Genève, 1893, 4to. *Berlin und Neuchatel*, 1894

The Editor. Astronomical Journal, Nos. 319–346, 4to. *Boston*, 1894–95

The Society. Astronomical Society of the Pacific, Publications, Nos. 36–41. 8vo. *San Francisco*, 1894–95

The Editor. Astronomie, L', Revue mensuelle d'astronomie populaire, de météorologie, et de physique du globe, publiée par C. Flammarion, année xiii. 7–12. *Paris*, 1894

—— Astronomische Mittheilungen, No. lxxxiv., herausgegeben von A. Wolfer, 8vo. *Zürich*, 1894

—— Astronomische Nachrichten, Nos. 3235–3290, 4to. *Kiel*, 1894–95

The Editors. Astronomy and Astro-Physics, Nos. 126–129, 8vo. *Northfield, Minn.*, 1894

—— Astro-Physical Journal, vol. i. 1–5, 8vo. *Chicago*, 1895

The Editor. Athenæum, The, Nos. 3476–3528, 4to. *London*, 1894–95

The Association. Australasian Association for the Advancement of Science, Report of the fifth meeting, held at Adelaide, South Australia, 1893, 8vo. *Adelaide and Sydney*, 1894

The Author. Barnard, E. E., Micrometrical observations of the fifth satellite of *Jupiter* during the opposition of 1893, with measures of diameters of *Jupiter*, 1892–94, 4to. *Boston*, 1894

—— —— Photographs of Gale's comet, 8vo. *Northfield, Minn.*, 1894

—— —— Photograph of a remarkable comet; photograph of M. 8 and the Trifid Nebula; the great photographic nebula of Orion encircling the belt and θ Nebula; the form of the disc of the III. satellite, and phenomena of the occultation of a satellite of *Jupiter*, 8vo. *Northfield, Minn.*, 1894

—— —— —— The great red spot, and other markings on *Jupiter*; on the exterior nebulosities of the *Pleiades*, 8vo. *Northfield, Minn.*, 1894

—— —— Photographs of Swift's Nebula in *Monoceros*, N.G.C. 2237, 8vo. *Northfield, Minn.*, 1894

Barnard, E. E., Micrometrical observations of Nova (T) Aurigæ, made with the 36-inch equatorial of the Lick Observatory, 4to. *Kiel*, 1894 — The Author.

—— Observations of the transits of *Mercury*, 1891 May 9 and 1894 Nov. 9–10, 4to. *Boston*, 1895 — ——

—— Photographs of the Milky Way, 8vo. *Chicago*, 1895 — ——

Batavia, Koninklijke Natuurkundige Vereeniging, Natuurkundig Tijdschrift voor Nederlandsch-Indië, Deel liii., 8vo. *Batavia*, 1893 — The Society.

Batavia, Magnetical and Meteorological Observatory. Observations, vol. xvi., 1893, 4to. *Batavia*, 1894 — The Observatory.

—— Rainfall in the East Indian Archipelago, 15th year, 1893, 8vo. *Batavia*, 1894 — ——

Belfast Natural History and Philosophical Society, Report and Proceedings for the session 1893-94, 8vo. *Belfast*, 1895 — The Society.

Berlin, Astronomisches Jahrbuch für 1897, mit Angaben für die Oppositionen der Planeten $\frac{1}{368}$, für 1895, 8vo. *Berlin*, 1895 — The Observatory, Berlin.

Berlin, Centralbureau der Internationalen Erdmessung, Verhandlungen der vom 5 bis 12 September 1894 in Iunsbrück abgehaltenen Conferenz der Permanenten Commission, 4to. *Berlin*, 1895 — The Bureau.

Berlin, Königlich-preussische Akademie der Wissenschaften, Abhandlungen aus dem Jahre 1893, 4to. *Berlin*, 1893 — The Academy.

—— Sitzungsberichte, 1894, i—1895, xx., 8vo. *Berlin*, 1894–95 — ——

Berlin, Physikalische Gesellschaft, Die Fortschritte der Physik im Jahre 1888, Abth. iii., 8vo. *Braunschweig*, 1894 — The Society.

Bologna, Reale Accademia delle Scienze, Memorie, serie V. tomo iii. Memorie della sezione delle scienze fisiche e mathematiche, 4to. *Bologna*, 1893 — The Academy.

Bombay Branch of the Royal Asiatic Society, Journal, vol. xviii., Nos. 49–50, 8vo. *Bombay*, 1894 — The Society.

Bombay, Government Observatory, Magnetical and Meteorological Observations, made in the year 1893, under the direction of C. Chambers, fol. *Bombay*, 1894 — The Observatory.

—— Brief sketch of the Meteorology of the Bombay Presidency in 1893-94, fol. *Bombay*, 1894 — ——

The Observatory. Bordeaux, Observatoire, Annales, publiées par G. Rayet, tome v., 4to. *Paris et Bordeaux*, 1894

The Society. Bordeaux, Société des Sciences physiques et naturelles, Mémoires, série IV., tome iii. 2 ; tome iv. 1–2, 8vo. *Paris and Bordeaux*, 1893–94

——— —— Appendice au tome iv., Observations pluviométriques et thermométriques faites dans le département de la Gironde, 1892–93, par G. Rayet, 8vo. *Bordeaux*, 1893

The Author. Breach, E., Dauntless Astronomy, 16mo. *Portsmouth*, 1894

——— Brédikhine, Th., Mouvement des substances émises par les Comètes, 1893 ii. et 1893 iv., 4to. *St.-Pétersbourg*, 1895

——— —— Sur les Perséides observées en Russie en 1894, 4to. *St.-Pétersbourg*, 1895

The Association. British Association for the Advancement of Science, Report of the sixty-fourth meeting, held at Oxford, 1894, 8vo. *London*, 1895

——— —— List of Officers, Council, and Members, 1894, 8vo. *London*, 1894

——— British Astronomical Association, Journal, vol. iv. No. 7—v, No. 7, 8vo.

——— —— Memoirs, vol. ii. parts 3–6, 8vo. *London*, 1894–95

The Observatory. Brussels, Observatoire Royal de Belgique, Annuaire, 1895 (62e année), 16mo. *Bruxelles*, 1895

The Society. Brussels, Société Belge d'Astronomie, Statuts, 8vo. *Bruxelles*, 1895

The Institute. Buda-Pest, Königl. Ung. Central-Anstalt für Meteorologie und Erdmagnetismus, Band xxi., 1891, 4to. *Buda-Pest*, 1894

The Office. Buenos Aires, Oficina Meteorológica Argentina, Anales, por su director G. G. Davis, tomo ix., Clima de Córdoba, part i.–ii., 4to. *Buenos Aires*, 1893–94

The Edittors. Bulletin des Sciences Mathématiques, série II., tome xviii. 4–xix. 6, 8vo. *Paris*, 1894–95

The Author. Burnham, S. W., The orbit of 9 *Argûs* (β 101), 8vo. *Northfield, Minn.*, 1893

——— —— Life and work of E. E. Barnard, 8vo. *Northfield, Minn.*, 1894

——— —— How to find the orbit of a double star by a graphical method, 8vo. *Northfield, Minn.*, 1894

Burnham, S. W., The variable proper motion of *Procyon* *Northfield, Minn.*, 1894	The Author.
—— Double-star observations made with the thirty-six inch and twelve-inch refractors of the Lick Observatory, 1888–92, 4to. *Sacramento*, 1894	——
Calcutta, Asiatic Society of Bengal, Journal, part ii., vol. lxii., 4—lxiv. 1, 8vo. *Calcutta*, 1894–95	The Society.
—— Proceedings, 1893, 10—1895, 3, 8vo. *Calcutta*, 1894–95	——
—— Annual address by the President, 1894, 8vo. *Calcutta*, 1894	——
Cambridge Philosophical Society, Proceedings, vol. viii., parts 3–4, 8vo. *Cambridge*, 1894–95	——
Camera Club, Journal, Nos. 98–109, 4to. *London*, 1894–95	The Club.
Canada, Dominion of, Report of the meteorological service for the year ending Dec. 31, 1889, by C. Carpmael, 8vo. *Ottawa*, 1893	The Canadian Government.
Canada, Royal Society, Proceedings and Transactions for the year 1893, vol. xi., 4to. *Ottawa*, 1894	The Society.
Cape of Good Hope, Royal Observatory, Heliometer observations for determination of stellar parallax, by David Gill, 8vo. *London*, 1893	The Observatory.
—— Report of H.M. Astronomer for 1879–93, 4to. *London*, 1893–94	——
Cape Town, South African Philosophical Society, Transactions, vol. v., part 2, 8vo. *Cape Town*, 1893	The Society.
Cardiff, Astronomical Society of Wales, Journal, vol. i., Nos. 1–5, 16mo. *Cardiff*, 1895	——
Cayley, A., The collected mathematical papers of, vol. vii., 4to. *Cambridge*, 1894	The Author.
Charkow, Universitäts-Sternwarte, Publication, Heft 2, 3, 8vo. *Charkow*, 1893–95	The Observatory.
Clerk of the Weather, the, Edited by H. Clements, vol. i., No. 1, 4to. *London*, 1895	The Editor.
Contarino, Fr., Sulla determinazione della latitudine col metodo di Döllen, 4to. *Kiel*, 1894	The Author.
Copenhagen, Kongelige Danske Videnskabernes Selskab, Oversigt over det Forhandlinger, 1893, iii., 1894, i., 2, 8vo. *Kjöbenhavn*, 1893–94	The Society.

The Observatory. Cordoba, Observatorio Nacional Argentino, Resultados, vol. xvii.; Zonas de exploracion brillantez y posicion de todas las estrellas fijas hasta la décima magnitud, entre 32 y 42 grados de declinacion sud, con un atlas, 4to. and fol. *Buenos Aires*, 1894

The College. Cork, Queen's College, Calendar, 1894–95, 8vo. *Cork*, 1894

The Author. Cornu, A., La Synchronisation Électromagnétique, 4to. *Paris*, 1894

The Academy. Cracow, Académie des Sciences, Bulletin International, Comptes rendus des séances de l'année 1894, v.–1895, iv., 8vo. *Cracovie*, 1894-95

The Author. Davis, H. S., The parallax of η Cassiopeiæ deduced from the Rutherfurd photographic measures (Contributions from the Observatory of Columbia College, New York, No. 6), 8vo. *New York*, 1895

The School. Delft, École Polytechnique, Annales, tome viii. 1, 2, 4to. *Leide*, 1894

The Author. Deslandres, H., The Solar faculæ, 8vo. *London*, 1883

——— —— Loi de répartition des raies et des bandes, commune à plusieurs spectres de bandes : Analogie avec la loi de succession des sons d'un corps solide, 4to. *Paris*, 1887

——— —— Spectre de bandes ultra-violet des composés hydrogénés et oxygénés du carbone, 4to. *Paris*, 1888

——— —— Spectres de bandes ultra-violets des métalloides avec une faible dispersion, 4to. *Paris*, 1888

——— —— Organisation des recherches spectroscopiques avec le grand télescope de l'Observatoire de Paris, 4to. *Paris*, 1890

——— —— Propriété fondamentale commune aux deux classes de spectres, 4to. *Paris*, 1890

——— —— Recherches sur le mouvement radial des astres avec le sidérostat de l'Observatoire de Paris, 4to. *Paris*, 1891

——— —— Méthode nouvelle pour la recherche des bandes faibles dans les spectres de bandes. Application au spectre des hydrocarbures, 4to. *Paris*, 1891

——— —— Sur les spectres de bandes du carbone dans l'arc électrique, 8vo. *Paris*, 1891

——— —— Recherches nouvelles sur l'atmosphère solaire (2 memoirs), 4to. *Paris*, 1891–9

Deslandres, H., Sur une protubérance remarquable, 4to. *Paris*, 1892 — The Author.

—— Résultats nouveaux sur l'hydrogène obtenus par l'étude spectrale du Soleil; rapprochements avec l'étoile nouvelle du Cocher, 4to. *Paris*, 1892 ——

—— Transformation du grand télescope de l'Observatoire de Paris pour l'étude des vitesses radiales des astres: Résultats obtenus, 4to. *Paris*, 1892 ——

—— Spectre du pôle négatif de l'azote: loi générale de répartition des raies dans les spectres de bandes, 4to. *Paris*, 1892 ——

—— Contribution à la recherche de la couronne solaire en dehors des éclipses totales (2 memoirs), 4to. *Paris*, 1893 ——

—— Sur l'observation de l'éclipse totale du soleil du 16 avril, faite à Foundiongue (Sénégal), 4to. *Paris*, 1893 ——

—— Recherches photographiques sur les flammes de l'atmosphère solaire, 8vo. *Paris*, 1893 ——

—— Sur l'enregistrement des éléments variables du soleil, 4to. *Paris*, 1893 ——

—— Sur la recherche de la partie de l'atmosphère coronale du soleil projetée sur le disque, 4to. *Paris*, 1893 ——

—— Appareils enregistreurs de l'atmosphère solaire, 8vo. *Paris*, 1894 ——

—— Sur la photographie de la chromosphère du soleil, 4to. *Paris*, 1894 ——

—— Sur la chromosphère du soleil; réponse à M. Hale, 4to. *Paris*, 1894 ——

—— Images spéciales du soleil données par les simples qui correspondent aux raies noires du spectre solaire, 4to. *Paris*, 1894. ——

—— Recherches sur les mouvements de l'atmosphère solaire, 4to. *Paris*, 1894 ——

—— Étude des gaz et vapeurs du Soleil, 8vo. *Paris*, 1894 ——

—— Sur l'origine électrique de la chromosphère solaire, 8vo. *Paris*, 1894 ——

—— Sur l'enregistrement de la chromosphère et de la photosphère du Soleil par la méthode des sections successives, 8vo. *Paris*, 1894 ——

Dijon, Académie des Sciences, Arts et Belles-lettres, Mémoires, série IV., tome iv., Années 1893–94, 8vo. *Dijon*, 1894 — The Academy.

Astronomical Society of Russia.	Döllen, W., Éphémérides des étoiles pour la détermination de l'heure et de l'azimut au moyen d'un instrument des passages portatif établi dans le plan vertical de la polaire pour 1895, 8vo. *St.-Pétersbourg*, 1895
The Author.	Donner, Anders, Détermination des constantes nécessaires pour la réduction les clichés pris à Helsingfors pour la construction du Catalogue photographique jusqu'à la onzième grandeur, 4to. *Helsingfors*, 1894
———	Douglass, A. E., A cloud-like spot on the terminator of *Mars*, 8vo. *Chicago*, 1895
———	Dreyer, J. L. E., Micrometrical Observations of Nebulæ made at the Armagh Observatory, 4to. *Dublin*, 1894
The Academy.	Dublin, Royal Irish Academy, Proceedings, 3rd series, vol. iii. 2, 3, 8vo. *Dublin*, 1894
———	——— Transactions, vol. xxx. 11, 12, 4to. *Dublin*, 1894
The Author.	Easton, C., Sur la distribution apparente des étoiles dans une partie de la Voie lactée, 4to. *Kiel*, 1894
Royal Observatory Edinburgh.	Edinburgh Circular, No. 43.
	Edinburgh Review, The, No. 370, 8vo. *London*, 1894
The Publishers (G. Phillip & Son).	Elger, T. G., The moon; a full description and map of its principal physical features, 8vo. *London*, 1895
The Editor.	English Mechanic, The, and World of Science, Nos. 1525–1577, fol. *London*, 1894–95
The Author.	Fényi, J., On a very large protuberance observed Dec. 24, 1894, 8vo. *Chicago*, 1895
The Hydrographer	Field, A. M., Commander, Longitude of Malacca, Straits Settlements, fol. *London*, 1894
The Author.	Field, Osgood, The Fields of Sowerby, near Halifax, England, and of Flushing, New York, 4to. *London*, 1895
The Editor.	Flammarion, C., Annuaire Astronomique et météorologique pour 1895, 8vo. *Paris*, 1894
The Author.	Forbes, George, On Comets and Ultra-Neptunian planets, 4to. *Edinburgh*, 1880
———	Franz, J., Darlegung der Ephemeridenrechnung von Mösting A, 4to. *Kiel*, 1894
———	——— Der Einfluss der Phase auf die scheinbare Lage von Mösting A, 4to. *Kiel*, 1894

Franz, J., Königsberger Meridianbeobachtungen von Mösting A, 4to. *Kiel*, 1894 — The Author.

—— Ephemeride zur Beobachtung des Mondkraters Mösting A, 8vo. *Königsberg*, 1894 — ——

Gaillot, A., Addition à la théorie du mouvement par Le Verrier, et rectification des tables, 4to. *Paris*, 1895 — ——

Galle, J. G., Verzeichniss der Elemente der bisher berechneten Cometenbahnen, nebst Anmerkungen und Literatur-Nachweisen; neu bearbeitet, ergänzt, und fortgesetzt bis zum Jahre 1894, 8vo. *Leipzig*, 1894 — ——

—— Ueber die Bahn des am 4. December 1893 vornehmlich in Schlesien beobachteten hellen Meteors, 8vo. *Breslau*, 1894 — ——

Galway, Queen's College, Calendar for 1894–95, 8vo. *Dublin*, 1895 — The College.

Gautier, Raoul, Le service chronométrique à l'Observatoire de Genève, 8vo. *Genève*, 1894 — The Author.

Geneva, Société de Physique et d'Histoire naturelle, Mémoires, tome xxxii., partie 1, 4to. *Genève*, 1894–95 — The Society.

—— Société des Arts, Concours International de Réglage pour Chronomètres in 1896, 8vo. *Genève*, 1894 — ——

Geological Society, Quarterly Journal, Nos. 199–202, 8vo. *London*, 1894–95 — ——.

Giberne, Agnes, Radiant Suns; a sequel to "Sun, Moon and Stars"; with a preface by Mrs. Huggins, 8vo. *London*, 1895 — The Author.

Ginzel, F. K., Über einen Versuch, das Alter der Vedischen Schriften aus historischen Sonnenfinsternissen zu bestimmen, 8vo. *Prag*, 1894 — W. T. Lynn.

Glasenapp, S. de, Observations Astronomiques, faites à Abastouman, 8vo. *St.-Pétersburg*, 1894 — The Author.

Glasgow, Mitchell Library, Twelfth General Report, 8vo. *Glasgow*, 1895 — The Library.

Gore, J. E., The worlds of space, 8vo. *London*, 1894 — M. C. Sharp.

Gothard, E. von, Erfahrungen auf dem Gebiete der Himmelsphotographie, 8vo. *Halle*, 1894 — E. von Gothard.

Göttingen, Königliche Gesellschaft der Wissenschaften, Nachrichten, Mathematisch-physikalische Klasse, 1894, 1–1895, 1, 8vo. *Göttingen*, 1894–95 — The Society.

The Observatory. Göttingen, Königliche Sternwarte, Astronomische Mittheilungen, herausgegeben von W. Schur, Theil iii., L. Ambronn, Triangulation der Plejadengruppe, 4to. *Göttingen*, 1894

The Author. Grandi, Luigi, Lettera aperta agli astronomi, 4to. 1894

The Observatory. Greenwich, Royal Observatory, Astronomical and Magnetical and Meteorological observations made in the year 1891, under the direction of W. H. M. Christie, 4to. *London*, 1893

——— —— Astronomical Results, 1891, 4to. *London*, 1893

——— —— Magnetical and Meteorological Results, 1891, 4to. *London*, 1893

——— —— Spectroscopic and photographic results, 1891, 4to. *London*, 1893

——— —— Five-year catalogue of 258 fundamental stars for 1890, 4to. *London*, 1893

——— —— Rates of chronometers and deck watches, 1893–94, 4to, *London*, 1894

——— —— Assumed mean right ascensions of clock stars and circumpolar stars for 1895·0, 4to. *London*, 1894

——— —— Report of the Astronomer Royal to the Board of Visitors, 1894–95, 4to. *London*, 1895

The Author. Grubb, Sir H., The development of the astronomical telescope, 8vo. *London*, 1894

——— Gruson, Hermann, Im Reiche des Lichtes: Sonnen, Zodiakallichte, Kometen: Dämmerungslicht-Pyramiden nach den ältesten ägyptischen Quellen, 8vo. *Braunschweig*, 1895

Berne University. Gubler, Ed., Verwandlung einer hypergeometrischen Reihe im Anschluss an das Integral $\int_0^\infty {}^a\mathrm{J}(x)e^{-bx}x^{r-1}dx$. Inaugural Dissertation, 8vo. *Uster*, 1894

The Author. Guillaume, J., Observations du soleil faites à l'équatorial Brunner de l'Observatoire de Lyon, 8vo.

——— Gyldén, H., Zur Transformation der periodischen Aggregate, 4to. *St. Petersburg*, 1894

The Museum. Haarlem, Musée Teyler, Archives, série II., vol. iv., 3, 8vo. *Haarlem*, 1894

The Author. Hale, G. E., The Astrophysical Journal, 8vo. *Northfield, Minn.*, 1894

Hale, G. E., On some attempts to photograph the solar corona without an eclipse, 8vo. *Northfield, Minn.* — The Author.

Hamburg, Sternwarte, Bericht des Direktors, 1894, 4to. *Hamburg*, 1894 — The Observatory.

—— Mittheilungen; No. 1, G. Rümker, Positionsbestimmungen von Nebelflecken und Sternhaufen; No. 2, C. Stechert, Bahnbestimmung des Planeten (258) Tyche, 4to. *Hamburg*, 1895 — ——

Harvard College Astronomical Observatory, Annals, vol. xxii., part i., Investigations in Astronomical Photography, by W. H. Pickering, 4to. *Cambridge, Mass.*, 1895 — ——

—— Annals, vol. xxxv., Journal of the Zone Observations, 4to. *Waterville, Me.*, 1894 — ——

—— Annals, vol. xl., part iii.; vol. xli., No. 1, Meteorological Observations, 4to. *Cambridge, Mass.*, 1894 — ——

—— Forty-ninth Annual Report of the Director, 1894, 8vo. *Cambridge, Mass.*, 1894 — ——

Hasselberg, B., Ueber das Linienspectrum des Sauerstoffs, 8vo. *Leipzig*, 1894 — The Author.

—— Sur les observations spectroscopiques des nébuleuses faites à Mount Hamilton à l'aide du grand réfracteur de Lick, par J. E. Keeler, 4to. *Roma*, 1895 — ——

Helsingfors, Finska Vetenskaps-Societet, Öfversigt af Förhandlingar, xxxv., 1892–93, 8vo. *Helsingfors*, 1893 — The Society.

—— —— Acta Societatis Scientiarum Fennicæ, tomus xix., 4to. *Helsingfors*, 1893 — ——

—— —— Bidrag till Kännedom Finlands Natur och Folk, 52, 53, 8vo. *Helsingfors*, 1893 — ——

Helsingfors, Institut Météorologique Central, observations météorologiques, 1881–88, 4to. *Kuopio*, 1893–94 — The Institute.

—— Observations, vols. vi.–viii., xi. Observations météorologiques faites à Helsingfors, 1887–89, 1892, 4to. *Helsingfors*, 1893 — ——

Helsingfors, Société de Géographie de Finlande, Fennia, 9, 11, 8vo. *Helsingfors*, 1894 — The Society.

Herény, Physikalisches Observatorium, Meteorologische Beobachtungen im Jahre 1891, herausgegeben von E. von Gothard, 4to. *Budapest*, 1894 — E. von Gothard.

The Author. Hill, G. W., Literal expression for the motion of the Moon's perigee, 4to. 1894

The Editor. Himmel und Erde ; illustrierte naturwissenschaftliche Monatsschrift, herausgegeben von der Gesellschaft Urania ; Jahrgang vi. 10–vii. 9, 8vo. *Berlin*, 1894–95

M. C. Sharp. Hind, J. R., The illustrated London Astronomy, 8vo. *London*, 1853

The Author. Holden, E. S., A brief account of the Lick Observatory, 8vo. *Sacramento*, 1895

The Observatory. Hong-Kong Observatory, Observations and researches made in the year 1893, by W. Doberck, fol. *Hong-Kong*, 1894

British Horological Institute. Horological Journal, The, a monthly paper for watch and chronometer makers, Nos. 431–442, 8vo. *London*, 1894–95

The Author. Huggins, Margaret, L., The Astrolabe, 8vo. *Northfield, Minn.*, 1894

The Society. Hull, Literary and Philosophical Society, Annual Report of the Council and Transactions, 1894–95, 8vo. *Hull*, 1895

H. M.'s Government in India. India, Great Trigonometrical Survey, Catalogue of stars for the epoch Jan. 1, 1892, 4to. *Dehra Dún*, 1893

——— India, Survey Department, General Report on the operations during 1892–93, fol. *Calcutta*, 1894

The Editor. Indian Engineering, vol. xv. 20—xvii. 20, fol. *Calcutta*, 1894–95

The Author. Inwards, R., On some phenomena of the upper air, 8vo. *London*, 1894

Lieut. C. W. Baillie. Japanese astronomical works (four works).

The Author. Jenkins, B. G., Tellustria ; a method for determining astronomically the variations in the temperature and pressure of the atmosphere, 8vo. *London*, 1894

——— Johnson, R. C., The new astronomy ; an account of astrophotography, 8vo. *Liverpool*, 1894

——— Kammermann, A., Résumé météorologique de l'année 1893 pour Genève et le Grand Saint-Bernard, 8vo. *Genève*, 1894

The University. Kasan, Imperial University, Scientific Memoirs, 1894, No. 3–1895, No. 4 [in Russian], 8vo. *Kasan*, 1894–95

——— ——— Observations of variable stars of the Algol type, 1891–92 [in Russian], 8vo. *Kasan*, 1893

Kasan, Observatoire Astronomique de l'Université Impériale. Observations with the transit instrument in the prime vertical, and Catalogue of the declinations of 202 stars, 4to. *Kasan*, 1893 — The Observatory.

Kasan, Observatoire Astronomique de l'Université Impériale, Resultate der Beobachtungen in Kasan betreffend die Veränderlichkeit der Polhöhe. I. Beobachtungsreihe 30 April 1892—12 Juli 1893, von A. M. Kowalski, 4to. *Kasan*, 1894 — ——

—— Observations of the Perseids [in Russian], 8vo. *Kasan*, 1894 — ——

—— Ephemerides of the Sun and Moon for the year 1894, 8vo. *Kasan*, 1893 — ——

Keeler, J. E., On the spectra of the *Orion* nebula, and the *Orion* stars, 8vo. *Northfield, Minn.*, 1894 — The Author.

—— Spectroscopic observations of nebulæ made at Mount Hamilton, California, with the 36-inch refractor of the Lick Observatory. *Sacramento*, 1894 — ——

Kew Observatory, Report of the Incorporated Kew Committee for the year 1894, 8vo. *London*, 1894 — The Committee.

Kostinsky, S., Sur la parallaxe de β *Cassiopeiæ*, 4to. *St.-Pétersbourg*, 1894 — The Author.

Von Kuffner'sche Sternwarte, Publicationen, herausgegeben von L. de Ball, Band iii., 4to. *Wien*, 1894 — The Observatory.

Langley, S. P., Nouvelles recherches sur la région infra-rouge du spectre solaire, 4to. *Paris*, 1894 — The Author.

Laplace, P. S. de, Œuvres complètes, tome x., 4to. *Paris*, 1894 — The Academy of Sciences, Paris.

Larlein, Henry, Elliptical orbits ; their distinctive mechanical characteristics and their possible origin, 8vo. *London*, 1895 — The Author.

Leiden, Verslag van den staat der Sterrenwacht te Leiden, 1893-94. H. G. van de Sande Bakhuyzen, 8vo. *Leide*, 1894 — The Observatory.

Leipzig, Astronomische Gesellschaft, Vierteljahrsschrift, Jahrgang 29, Heft. 1-3, 8vo. *Leipzig*, 1894 — The Society.

—— Catalog, Erste Abtheilung, 6$^{\text{tes}}$ Stück ; Zone +40° bis +50°. Beobachtet auf der Sternwarte zu Bonn, 4to *Leipzig*, 1894 — ——

The Society. Leipzig, Königlich Sächsische Gesellschaft der Wissenschaften, Abhandlungen der mathematisch-physischen Classe, Band xxi. 2–xxii. 1., 8vo. *Leipzig*, 1894-95

——— —— —— Berichte über die Verhandlungen, 1894, ii.—1895, i., 8vo. *Leipzig*, 1894-95

The Observatory. Lick Observatory of the University of California, Publications, vol. ii., double star measures, by S. W. Burnham; vol. iii. selenographical studies, by L. Weinek; spectroscopic observations of nebulæ, by J. E. Keeler, &c., 4to. *Sacramento*, 1894

The Academy. Lisbon, Academia Real das Sciencias; Jornal de sciencias mathematicas, physicas e naturaes, Nos. xlvi.–xlviii., 1887-88, 8vo. *Lisboa*, 1887-88

——— —— —— Segunda serie, tom. i.—iii., 8vo. *Lisboa*, 1890-95

——— —— Memorias, Classe de sciencias mathematicas, physicas e naturaes, Nova serie, tomo vi., Parte II., 4to. *Lisboa*, 1887

——— —— Sessão publico em 17 de Dezembro de 1893, 8vo. *Lisboa*, 1893

——— —— Elogio historico de S. M. el Rei d. Luiz i., 4to. *Lisboa*, 1890

——— —— —— A. H. de Carvalho e Aranjo, 4to. *Lisboa*, 1890

——— —— —— A. V. Lourenço, 4to. *Lisboa*, 1893

——— —— Machado, V., A Electricidade; estudo de algumas das suas principaes applicações, 8vo. *Lisboa*, 1887

——— —— —— As applicações medicas e cirurgicas da electricidade, 8vo. *Lisboa*, 1895

——— —— Machado, V. e A., Chimica Geral e Analyse Chimica, 2 vols., 8vo. *Lisboa*, 1892

——— —— Chagas, M. Pinheiro, Os descobrimentos Portuguezes e os de Colombo: tentativa de coordenação historica, 8vo. *Lisboa*, 1892

——— —— Coelho, J. M., Latino, Compendio de mineralogia morphologia mineral, 8vo. *Lisboa*, 1892

——— —— Horta, F. P., Estudo elementar dos determinantes; seguido de uma parte complimentar relativa, principalmente, aos determinantes funccionaes, 8vo. *Lisboa*, 1889

The Observatory. Liverpool Observatory, Bidston, Extracts from the report of the Director, and meteorological results deduced from observations taken 1892 and 1893, 8vo. *Liverpool*, 1894

Lorentzen, G., Ueber die Untersuchung der Scalen eines Heliometers, 4to. *Kiel*, 1894. — The Author.

Lund Observatoire, Observations des étoiles de la Zone, entre 35° et 40° de déclinaison boréale, réduites à l'équinoxe moyen de 1875·0, par N. C. Dunér et F. Engström, tome ii., Nos. 4, 5, 4to. *Lund*, 1894–95 — The Observatory.

Lynn, W. T., Remarkable Comets, 3rd edition, 8vo. *London*, 1895 — The Author.

Madras, Government Observatory, Results of observations of the Fixed Stars made with the meridian circle in the years 1880–87, under the direction of N. R. Pogson, by C. Michie Smith, vols. vii., viii., 4to. *Madras*, 1894 — The Observatory.

Madrid, Academia de Ciencias exactas, fisicas y naturales, Anuario, 1895, 16mo. *Madrid*, 1895 — The Academy.

Madrid, Observatorio, Observaciones meteorológicas, 1892–93, 8vo. *Madrid*, 1894. — The Observatory.

Manchester Literary and Philosophical Society, Memoirs and Proceedings, series IV., vol. viii. 3—ix. 2, 8vo. *Manchester*, 1894–95 — The Society.

Manchester Public Free Libraries, 42nd Annual Report, 8vo. *Manchester*, 1894 — The Library.

Manila, Observatorio meteorológico, observaciones, 1892, 8–1894, 5 ; y Appendice al año 1892, fol. *Manila*, 1894 — The Observatory.

—— La Seismologia en Filipinas, por M. Saderra Masó, 4to. *Manila*, 1895 — ——

Mauritius, Royal Alfred Observatory, Meteorological Observations, 1893, fol. *Mauritius*, 1894 — ——

Melbourne Observatory, Monthly record of results of observations in meteorology, terrestrial magnetism, &c., &c., taken under the superintendence of R. L. J. Ellery, 1893–4, 8vo. *Melbourne*, 1893–94 — ——

Meteorological Office, Meteorological observations at stations of the second order for the year 1890, 4to. *London*, 1894 — The Office.

—— Weekly Weather Report, vol. xi. 23–xii. 23, 4to. *London*, 1894–95 — ——

Montpellier, Académie des sciences et lettres, Mémoires de la section des sciences, série II., tome i. 3, 4, tome ii. 1, 8vo. *Montpellier*, 1893–94 — The Academy.

The Society. Moscow, Société Impériale des Naturalistes, Bulletin, année 1894, Nos. 1–4, 8vo. *Moscou*, 1894–95

The Academy. Munich, Königlich-Bayerische Akademie der Wissenschaften, Sitzungsberichte der mathematisch-physikalischen Classe, 1894, ii.–1895, i., 8vo. *München*, 1894–95

——— Naples, Reale Accademia delle scienze fisiche e matematiche, Atti, serie II., vol. vi., 4to. *Napoli*, 1894

——— —— Rendiconto, serie II., vol. viii. 3–serie III., vol. i. 4, 4to. *Napoli*, 1894–95

The Observatory. Naples, Osservatorio di Capodimonte, Osservazioni meteorologiche, 1893, 4to. *Napoli*, 1894

——— —— Riassunti decadici e mensuali delle osservazioni meteoriche, fatte nell' anno 1892, nota di F. Brioschi, 4to. *Napoli*, 1893

——— Natal Observatory, Annual Report of the Superintendent, 1893–94, fol. *Pietermaritzburg*, 1894

The Editor. Naturwissenschaftliche Rundschau, Jahrgang ix. 24–x. 24, 4to. *Braunschweig*, 1894–95

Lords Commrs. of Admiralty. Nautical Almanac and astronomical ephemeris for the year 1898, 8vo. *London*, 1895

——— —— Ditto, part 1 (containing such portions as are essential for navigation), 8vo. *London*, 1895

Nautical Almanac Office. —— Circular No. 16, Local particulars of the total eclipse of the Sun, 1898, January 21–22, 8vo. *London*, 1895

American Ephemeris Office. Newcomb, Simon, The elements of the four inner planets and the fundamental constants of astronomy. (Supplement to the American Ephemeris for 1897), 8vo. *Washington*, 1895

The Society. New York Mathematical Society, Bulletin, vol. iii. 9–series II., vol. i., 8, 8vo. *New York*, 1894–95

The Author. Nobile, A., Risultate di talune osservazioni di distanze zenitali, 4to. *Napoli*, 1894

——— —— Studio iniziale del collimatore del cerchio meridiano Reichembach-Heurtaux, 4to. *Napoli*, 1894

——— —— Saggio di determinazione diretta della costante di una linea geodetica nell' ellissoide di rivoluzione schiacciato date le coordinate di due punti, 4to. *Napoli*, 1894

Nobile, A., Ascensioni Rette determinate simultaneamente a Capodimonte ed a Cordoba (Repubblica Argentina), 4to. *Napoli*, 1894 — The Author.

Observatory, The, a monthly review of Astronomy, Nos. 216-228, 8vo. *London*, 1894-95 — The Editors.

O-Gyalla, Astrophysikalisches Observatorium, Beobachtungen, Band xv., xvi., enthaltend Beobachtungen der Jahre 1892 und 1893, 4to. *Halle a. S.*, 1894 — Royal Hungarian Central Meteorological Institute.

O-Gyalla, Meteorologisch-Magnetische Central-Observatorium, Beobachtungen, 1894, Nos. 5-1895, 4, 4to. *Buda-Pest*, 1894-95 — ———

Open Court, The, Nos. 354-402, 4to. *Chicago*, 1894-95 — The Editor.

Oxford, Radcliffe Observatory, Catalogue of 6,424 stars for the epoch 1890, formed from observations made during the years 1880-93, under the superintendence of E. J. Stone, 4to. *Oxford*, 1894 — The Radcliffe Trustees.

Paris, Académie des Sciences, Comptes rendus hebdomadaires des séances, tome cxviii. 23-cxx. 22, 4to. *Paris*, 1894-95 — The Academy.

Paris, Bureau des Longitudes, Annuaire pour l'an 1895, 16mo. *Paris*, 1894 — Bureau des Longitudes.

—— Éphémérides des Étoiles de culmination lunaire et de longitude pour 1894, par M. Lœwy, 4to. *Paris*, 1893 — ———

Paris, Comité International Permanent pour l'exécution photographique de la carte du ciel, Bulletin, tome ii., fasc. 2, 4to. *Paris*, 1895 — Academy of Sciences.

Paris, Dépôt Général de la Marine, Annales Hydrographiques, série II., 1894, i., ii., 8vo. *Paris*, 1894 — Dépôt de la Marine.

Paris, École Polytechnique, Journal, Cahier lxiv., 4to. *Paris*, 1894 — The School.

Paris, Observatoire, Annales, Observations 1886-87, publiées sous la direction de F. Tisserand, 4to. *Paris*, 1894 — The Observatory.

—— Rapport Annuel, pour l'année 1893, par F. Tisserand, 4to. *Paris*, 1894 — ———

Paris, Société Astronomique de France, Bulletin, et revue mensuelle d'Astronomie, de météorologie et de physique du globe, 1895, 1-6, 8vo. *Paris*, 1895 — The Society.

Paris, Société Mathématique de France, Bulletin, tome xxii. 5-xxiii. 3, 8vo. *Paris*, 1894-95 — ———

The Society. Paris, Société Philomathique, Bulletin, série VIII., tome vi. 2–4, 8vo. *Paris*, 1894-95

The Hydrographer Penang, Longitude of, determined by means of telegraphic signals exchanged with Singapore, 1893, by Commander A. M. Field, Lieutenant W. H. D. Margesson, and A. Sutherland, fol. *London*, 1894

The Author. Perigal, H., Phases of Perigal's retrogressive Kinematic parabola, 16mo. *London*, 1894

The Society. Philadelphia, American Philosophical Society, Proceedings, Nos. 143–146, 8vo. *Philadelphia*, 1894

The Institute. Philadelphia, Franklin Institute, Journal, Nos. 822–834, 8vo. *Philadelphia*, 1894-95

The Society. Physical Society of London, Proceedings, xii. 4–xiii. 7, 8vo. *London*, 1894-95

The Author. Pickering, W. H., Schiaparelli's latest views regarding *Mars*, 8vo.

——— —— Recent Observations of the satellites of *Jupiter*, 8vo. *Northfield, Minn.*, 1894

The Author. Plassmann, J., Beobachtungen veränderlicher Sterne, vierter Theil, 8vo. *Warendorf*, 1895

The Observatory. Potsdam, Astrophysikalisches Observatorium, Publicationen, herausgegeben von H. C. Vogel, Band vii., Theil II.; Band x. [Scheiner, Spectra der helleren Sterne; Spörer, Beobachtungen von Sonnenflecken, 1893–95], 4to. *Potsdam*, 1895

The Institute. Potsdam, Königlich Preussische Geodätisches Institut, Jahresbericht des Direktors, 1893–94, 8vo. *Berlin*, 1894

——— —— Veröffentlichungen; Polhöhenbestimmungen im Harzgebiet, 1887–91, 4to. *Berlin*, 1894

——— —— Feier des hundertjährigen Geburtstages des verewigten General lieutenants Dr. J. J. Baeyer, 4to. *Berlin*, 1894

The Observatory. Prag, K. K. Sternwarte, Magnetische und Meteorologische Beobachtungen im Jahre 1893, Jahrgang 54, 4to. *Prag*, 1894

The Author. Prince, C. L., Observations on the climate of Uckfield, constituting a meteorological record for the district from 1843–1870, 8vo. *London*, 1871

Pritchett, Henry S., Ueber die Verfinsterungen der Saturntrabanten. Inaugural Dissertation, 4to. *München*, 1895 — The Author.

Puebla, Colegio Católico, Observaciones Meteorológicas, año de 1879, fol. *Puebla* — The College.

—— Resumen de las observaciones meteorológicas practicadas durante el año de 1889, 8vo. *Puebla*, 1890 — ——

Queensland Branch of the Royal Geographical Society of Australasia, Proceedings, 9th Session, 1893-94, vol. ix., 8vo. *Brisbane*, 1894 — The Society.

Rajna, M., Sull' excursione diurna della declinazione magnetica a Milano, in relazione col periodo delle macchie solari, 8vo. *Milano*, 1895 — The Author.

Riefler, S., Die Präcisions-Uhren mit volkommen freien Echappement und neuen Quecksilber-Compensationspendel, 4to. *München*, 1894 — ——

Rio de Janeiro, Observatorio, Annuario para o anno de 1894, 8vo. *Rio de Janeiro*, 1893 — The Observatory.

Roberts, Isaac, A selection of photographs of stars, star clusters, and nebulæ, together with information concerning the instruments and the methods employed in the pursuit of celestial photography, 4to. *London*, 1894 — The Author.

Robertson, A., Sectionum Conicarum libri septem ; accedit tractatus de Sectionibus Conicis et de scriptoribus qui earum doctrinam tradiderunt (with MS. notes and additions by Francis Baily), 4to. *Oxonii*, 1792 — E. B. Knobel.

Rome, Accademia Pontificia de' Nuovi Lincei, Atti, anno xlvi., 4to. *Roma*, 1894 — The Academy.

Rome, Reale Accademia dei Lincei, Atti, anni 291-292, Serie V., Rendiconti, vol. iii., semestre i., fasc. 9-vol. iv., semestre i., fasc. 10, 4to. *Roma*, 1894-95 — ——

—— Catalogo delle ascensioni rette medie pel 1890·0, di 2,438 Stelle da A. di Legge e F. Giacomelli, 4to. *Roma*, 1894 — ——

Rome, Società degli Spettroscopisti Italiani, Memorie, vol. xxiii. 5-xxiv. 5, 4to. *Roma*, 1894 — The Society.

Rome, Specola Vaticana, Pubblicazioni, vol. iv., 4to. *Roma*, 1894 — The Observatory.

The Office.	Rome, Ufficio centrale meteorologico e geodinamico Italiano, Annali, vol. xii. 1, 2 ; vol. xiv. 1 ; vol. xv. 1, 4to. *Roma*, 1893–95
The Society.	Royal Dublin Society, Scientific Proceedings, new series, vol. viii., parts 1–2, 8vo. *Dublin*, 1894
———	—— Scientific Transactions, series II., vol. v., parts 1–4, 4to. *Dublin*, 1893
———	Royal Geographical Society, The Geographical Journal, vol. iv. 5–v. 6, 8vo. *London*, 1894–95
The Institution.	Royal Institution of Great Britain, Proceedings, vol. xiv., part 2, 8vo. *London*, 1895
The Society.	Royal Meteorological Society, Quarterly Journal, Nos. 92–94, 8vo. *London*, 1894–95
———	—— The Meteorological Record, Nos. 51–55, 8vo. *London*, 1894–95
———	Royal Photographic Society of Great Britain, Journal and Transactions, new series, vol. xviii. 10–xix. 9, 8vo. *London*, 1894–95
———	Royal Society of London, Proceedings, Nos. 334–345, 8vo. *London*, 1894–95
———	—— Catalogue of Scientific papers, 1174–83, vol. x., 4to. *London*, 1894–95
———	—— Philosophical Transactions (A), for the year 1894, vol. 185, part 1, 4to. *London*, 1895
———	—— List of Fellows, Nov. 30, 1894, 4to. *London*, 1895
———	—— Meteorological Council, Report for the year ending March 1894, 8vo. *London*, 1895
The Institution.	Royal United Service Institution, Journal, Nos. 196–207, 8vo. *London*, 1894–95
The Society.	Rugby School Natural History Society, Report for the year 1894, 8vo. *Rugby*, 1895
Agent General for New South Wales.	Russell, H. C., Observations of the transit of *Venus*, 9 December, 1874, made at stations in New South Wales, 4to. *Sydney*, 1892
The Author.	—— The progress of astronomical photography, 8vo. *Sydney*, 1894
The Academy.	St. Petersburg, Académie Impériale des Sciences, Bulletin nouvelle série, tome iv., No. 1–série V., tome ii., No. 2, 4to. *St.-Pétersbourg*, 1893–95

San Fernando, Almanaque Náutico para 1896, calculado en el Instituto y Observatorio di Marina, 8vo. *Madrid*, 1894 — The Observatory.

Scheiner, Julius, Untersuchungen über den Lichtwechsel Algols, nach den Mannheimer Beobachtungen von Professor Schönfeld, 1869-75. Inaugural Dissertation, 8vo. *Bonn*, 1882 — Dr. L. Becker.

—— A treatise on Astronomical Spectroscopy, being a translation of Die Spectralanalyse der Gestirne; translated, revised and enlarged by E. B. Frost, 8vo. *Boston*, 1894 — Prof. E. B. Frost.

Schiötz, O. E., Resultate der im Sommer 1893 in dem nördlichsten Theile Norwegens ausgeführten Pendelbeobachtungen (Norwegische Commission der Europäischen Gradmessung), 8vo. *Kristiania*, 1894 — The Author.

Schur, W., Bestimmung der Parallaxe des Sterns ψ 5 (56) *Aurigæ*, 4to. *Kiel*, 1894 — ——

—— Beobachtungen der veränderlichen Sterne δ *Cephei*, η *Aquilæ*, und β *Lyræ*, nach der Argelander'schen Methode der Stufenschätzungen, 4to. *Kiel*, 1895 — ——

Science (extract from), On a card catalogue of scientific literature, 4to. — Dr. H. P. Bowditch.

Sciences populaires, Nos. 1-3, 8vo. *Paris*, 1895 — The Editor.

Seeliger, H., Maxwell's und Hirn's Untersuchungen über die Constitution des Saturnringes, 8vo. *München*, 1894 — The Author.

—— Ueber den vierfachen Stern ζ *Cancri*, 8vo. *München*, 1894 — ——

Sirius; Zeitschrift für populäre Astronomie, Band xxvii. 7-xxviii. 6, 8vo. *Leipzig*, 1894-95 — The Editor.

Smith, H. J. S., The collected mathematical papers of, edited by J. W. L. Glaisher, 2 vols., 4to. *Oxford*, 1894 — Delegates of the Clarendon Press.

Società Meteorologica Italiana, Bollettino mensuale, pubblicato per cura dell' Osservatorio Centrale Carlo Alberto in Moncalieri, serie II., vol. iv. 6-12, 4to. *Torino*, 1894-95 — The Society.

Society of Arts, Journal, Nos. 2,168-2,220, 8vo. *London*, 1894-95 — ——

Souillart, C., Sur le degré d'approximation que comporte le calcul des latitudes dans la théorie des satellites de *Jupiter*; importance des termes du troisième degré, 8vo. *Paris*, 1895 — The Author.

The Author. Spitaler, R., Bahnbestimmung des Kometen 1851, III. (Brorsen), 4to. *Vienna*, 1894

——— Stevenson, Robert, Elasticity a mode of motion; being a popular description of a new and important discovery in science, 8vo. *San Francisco*, 1895

The Academy. Stockholm, Konglige Svenska Vetenskaps Akademie, Bihang till Handlingar, Band xix., Afdelning 1–3, 8vo. *Stockholm*, 1894

The Observatory. Stockholm, Observatory, Astronomiska Iakttagelser och Undersökningar, utgivna af H. Gyldén. Bandet v. 4 4to. *Stockholm*, 1895

——— Stonyhurst College Observatory, Results of meteorological, magnetical, and solar observations, by the Rev. W. Sidgreaves, 1894, 8vo. *Clitheroe*, 1895

The Society. Sydney, Royal Society of New South Wales, Journal and proceedings, vol. xxvii., 1893, 8vo. *Sydney*, 1894

The Observatory. Tacubaya, Observatorio Astronómico Nacional, Boletin, tomo i. 17–21, fol. *México*, 1894–95

——— —— Anuario para el año de 1895. Año xv., 16mo. *México*, 1894

The Publishers. (Partridge & Co.) Taylor, Lucy, Astronomers and their observations, 8vo. *London*, 1895

The Author. Tebbutt, John, Observations and orbit elements of Comet Gale, 1894, 8vo. *Sydney*, 1894

——— —— Report of Mr. Tebbutt's Observatory, for the years 1893, 1894, 8vo. *Sydney*, 1894–95

The Observatory. Tiflis, Physikalisches Observatorium, Beobachtungen im Jahre 1892, herausgegeben von J. Mielberg, 4to. *Tiflis*, 1894

The Author. Tischner, A., Le phénomène fondamental du système solaire, 8vo. *Leipzig*, 1895

——— Todd, Sir C., Meteorological work in Australia, a review, 8vo. *Adelaide*, 1894

The Society. Toronto, Astronomical and Physical Society, Transactions for the year 1894, 8vo. *Toronto*, 1895

——— Truro, Royal Institution of Cornwall, Journal, vol. xii., part i., 1894, 8vo. *Truro*, 1895

Turin, R. Accademia delle Scienze, Atti, vol. xxix. 2–xxx. 4, 8vo. *Torino*, 1894–95	The Academy.
—— Memorie, serie seconda, tomo xliv., 4to. *Torino*, 1894	——
United States Coast and Geodetic Survey, Report of the Superintendent for the year ending June 1892, part ii., 8vo. *Washington*, 1894	The Survey Office.
University College, London, Calendar, session 1894–95, 8vo. *London*, 1894	The College.
Upsala, Regia Societas Scientiarum, Nova Acta, series III., vol. xvi., 1893, 4to. *Upsaliæ*, 1893	The Society.
Very, T. W., Hail-storms, 8vo. *Pittsburgh*, 1894	The Author.
Vienna, Kaiserliche Akademie der Wissenschaften, Denkschriften, mathematisch-naturwissenschaftliche Classe, Band lx., 4to. *Wien*, 1893	The Academy.
—— Sitzungsberichte, mathematisch-naturwissenschaftliche Classe (Abtheilung II. a), Band cii. 8—ciii. 5, 8vo. *Wien*, 1893–94	——
—— —— (Abtheilung II. b.) Band cii. 8—ciii. 3, 8vo. *Wien*, 1893–94	——
Vienna, K. K. Gradmessungs-Bureau, Astronomische Arbeiten, ausgeführt unter der Leitung von Th. v. Oppolzer, herausgegeben von E. Weiss und R. Schram, Band v., vi., Längenbestimmungen, 4to. *Wien*, 1893–94	The Bureau.
Vienna, K. und K. Reichs-Kriegs-Ministerium, Marine-Section; Relative Schwerebestimmungen durch Pendelbeobachtungen ausgeführt in den Jahren, 1892–94, 8vo. *Wien*, 1895	Austrian Ministry of Marine.
Vienna, Österreichische Gradmessungs-Commission, Verhandlungen; Protokoll über die am 11. und 13. April 1894 abgehaltenen Sitzungen, 8vo. *Wien*, 1894	The Commission.
Vogel, H. C., Neue Untersuchungen über die Spectra der Planeten, 4to. *Berlin*, 1893	The Author.
Washburn Observatory of the University of Wisconsin, Publications, vol. vii., part 2. Meteorological observations, 4to. *Madison, Wis.*, 1894	The Observatory.
Washington, American Ephemeris and Nautical Almanac for the year 1897, 8vo. *Washington*, 1894	Office of the American Ephemeris.

Office of the American Ephemeris. Washington, Extract from the Annual Report of the Superintendent for 1894, 8vo. *Washington*, 1894

The Institution. Washington, Smithsonian Institution, Annual Report of the Board of Regents, 1892–93, 8vo. *Washington*, 1893–94

——— —— Report of S. P. Langley, Secretary, for the year ending June 1894, 8vo. *Washington*, 1895

——— —— Smithsonian Geographical Tables, by R. S. Woodward, 8vo. *Washington*, 1894

——— —— The varieties of the human species; principles and methods of classification, by G. Sergi, 8vo. *Washington*, 1894

——— —— Bibliography of Aceto-Acetic Ester, 8vo. *Washington*, 1894

——— —— Bureau of Ethnology, Tenth, Eleventh, and Twelfth Annual Report (1888–91), by J. W. Powell, 4to. *Washington*, 1893–94.

——— —— —— List of publications, 8vo. *Washington*, 1894

——— —— —— an Ancient Quarry in Indian Territory, 8vo. *Washington*, 1894

——— —— —— J. G. Pollard, The Pamunkey Indians of Virginia, 8vo. *Washington*, 1894

——— —— —— J. C. Pilling, Bibliography of the Wakshan languages, 8vo. *Washington*, 1894

——— —— —— C. Thomas, The Maya year, 8vo. *Washington*, 1894

The Survey. Washington, United States Geographical and Geological Survey: Contributions to North American Ethnology, vol. ix., 4to. *Washington*, 1893

The Observatory. Washington, United States Naval Observatory, Observations made during the year 1889, 4to. *Washington*, 1893

——— —— Magnetic Observations made during the year 1892, by S. T. Brown, 4to. *Washington*, 1893

——— —— Meteorological Observations and Results, 1889, 4to. *Washington*, 1893

U.S. Government. Washington, United States Treasury Department, Bulletin, Nos. 31–33 (Units of Electrical Measures; The constant of Aberration; The direction and intensity of the earth's magnetic force), 8vo. *Washington*, 1894–95

Webb, T. W., Celestial objects for common telescopes, 5th edition, revised and greatly enlarged, by the Rev. T. E. Espin, vol. ii., 8vo. *London*, 1894 — Messrs. Longman & Co.

Wilde, H., On the multiple proportions of the atomic weights of elementary substances in relation to the unit of hydrogen, 8vo. *Manchester*, 1895 — The Author.

—— On the evidence afforded by Bode's Law of a permanent contraction of the Radii Vectores of the planetary orbits, 8vo. *Manchester*, 1895 — ——

Wilson, W. E., and P. L. Gray, Experimental investigations on the effective temperature of the Sun, made at Daramona, Streete, co. Westmeath, 4to. *London*, 1894 — The Authors.

Winlock, W. C., An account of the progress of astronomy in the years 1889–92 (from the Smithsonian Report), 8vo. *Washington*, 1891–93 — The Institution.

Wolfer, A., Nekrolog von Rudolf Wolf, 8vo. *Leipzig*, 1894 — The Author.

Wolsingham Observatory, Report for the year 1894. —— Circular, Nos. 39–41. *Darlington*, 1894 — Rev. T. E. Espin.

Yale University, Astronomical Observatory, Report for the year 1893–94, 8vo. *New Haven*, 1894 — The Observatory.

Zenger, C. V., L'Électricité considérée comme un mouvement tourbillonnaire, 4to. *Paris*, 1894 — The Author.

Zürich, Naturforschende Gesellschaft, Vierteljahrsschrift, Band xxxix. 2–xl. 1, 8vo. *Zürich*, 1894–95 — The Society.

Zürich, Schweizerisch-meteorologisches Central-Anstalt, Annalen, 1892, Jahrgang 29, 4to. *Zürich*, 1894 — The Institute.

MSS., Photographs, Drawings, &c., presented to the Society.

Howlett, Rev. F., 3 volumes of drawings of Sun-spots. — Rev. T. Howlett.

Mohammad Al Achsasi Al Mouakket, Calendarium (Arabic, 17th Century MS.), sm. 4to. — E. B. Knobel.

Series of 61 transparencies from negatives of Comets, the Milky Way, &c., taken at the Lick Observatory. — E. E. Barnard.

Series of original negatives of *Jupiter* and *Saturn*, and enlarged positives on glass from negatives of the Moon and the total solar eclipse of 1860, taken by Warren de la Rue. — Ernest de la Rue.

MM. Lœwy et Puiseux. Three large transparencies of portions of the Moon, photographed with the Equatorial Coudé of the Paris Observatory.

Dr. L. Weinek. Twenty-four photographic enlargements of portions of the Lunar surface from negatives taken at the Paris Observatory by MM. Lœwy and Puiseux (paper prints).

Comte de la Baume Pluvinel. Two photographs of the eclipse of 1893 April, taken at Joal by the Comte de la Baume Pluvinel (glass positives).

M. H. Deslandres. Series of spectroheliograph photographs of solar prominences, faculæ, &c. (lantern slides).

M. W. Prinz. Agrandissements des photographies lunaires.

Dr. Isaac Roberts. Series of twenty-four lantern slides from photographs of nebulæ and clusters.

W. E. Wilson. Lantern slide from a negative of the cluster in *Hercules* (M. 13).

Dr. T. S. Sheldon. Photographs of *Orion*, portions of the Milky Way, &c. [negative, lantern slides, and enlargements].

P. Lowell. Series of twelve photographs from a globe of *Mars*, by P. Lowell (paper prints).

Dr. McClean. Three pastel drawings of the Moon by John Russell.

Executors of the late Mrs. Jackson-Gwilt. An Astronomical Scrap-book.

The Earl of Crawford. A 16th Century celestial globe, on bronze tripod stand.

Books purchased with the Turnor and Horrox Fund.

Avianus, Wilhelm, Directorium Universale ad multifaria matheseos problemata in toto terrarum Orbe, sine discrimine latitudinis locorum, uniformi Methodo, sine Calculo expeditè resolvenda, 4to. *Lipsiæ*, 1665

Bassantinus Scotus, J., Astronomia, fol. *Tornaesii* [*Lugduni*], 1599

Beutel, Tobias, Dissertatio Astronomica de Eclipsibus Solis, præcipue instanti d. II. Julii [Inaugural Dissertation], 4to. *Lipsiæ*, 1684

Blanchinus, Tabulæ Joā. Blanchini Bononiensis, cum plerisqu. additionibus ac nouis tabellis nup. impresse. Per L. Gauricū neapolit. castigate, 4to. *Venetiis*, 1526

Bormeister, S., Christlich vernünfftige Cometen-Betrachtung aus Gelegenheit desz in Monat December 1680. erschienenen grossen Cometen, 4to. *Nürnberg*, 1681

Bulletin Astronomique, 1894-95, 8vo. *Paris*, 1894–95

Ciel et Terre, 1894-95, 8vo. *Bruxelles*, 1894–95

Comet, 1665 April 8 (plate only).

Denores, Jason, Breve Trattato del Mondo et delle sve partis emplici et miste, 8vo. *Venetia*, 1571

—— Tavole del Mondo et della sphera . . . con la spheretta del Cl. M. Triphon Gabriele, 4to. *Padoua*, 1582

Dunn, S., A new and easy method for finding the longitude, 12mo. *London*, 1778

Fontenelle, B., The Life of Sir Isaac Newton, with an account of his writings, 4to. *London*, 1728

Giuffi, Jo. Ant., Tractatus de Eclipsibus, 4to. *Neapoli*, 1623

Gruneberg, Christ., Pandora mathematicarum tabularum, 12mo. *Francofurti ad Viadrum*, 1684

Gütner, Raphael, Fundamentalis, eaqvé Astronomica & Astrologica Doctrina de Conjunctionibus magnis . . . nec non speciatim de Conjunctione magna . . . die XII. Octob. anni currentis MDCLXIII., 4to. *Chemnitii*

Hagen, J. G., Synopsis der höheren Mathematik : Band ii. Geometrie d. algebraischen Gebilde, 4to. *Berlin*, 1894

Hancock, B., The astronomy of comets, 8vo. *London*, 1786

Higgs, G., Photographic Atlas of the normal solar spectrum

Hughes, W., A manual of mathematical geography, comprehending an inquiry into the construction of maps ; with rules for the formation of map-projections, 2nd edition, 8vo. *London*, 1852

Ilmer, G., et A. Krellius, Dissertatio [Inauguralis] de Sole, 4to. *Lipsiæ*, 1669

Knowledge ; an illustrated magazine of science, 1894–95, 4to. *London*, 1894–95

Leadbetter, C., Astronomy ; or the true system of the planets demonstrated, 4to. *London*, 1727

Mahmoud Effendi, Mémoire sur le Calendrier Arabe avant l'Islamisme, 8vo. *Paris*, 1858

Mayer, A., et E. Oloff, Phaenomena Solis a Luna d. I. Martii tecti, et Lunae per Vmbram Tellvris d. XVI. Martii obscvratae [Inaugural Dissertation], 4to. *Vittembergae*, 1737

Monforte, Ant. de, de Syderum intervallis, & magnitudinibus opusculum; cui accessit ejusdem tractatus de problematum determinatione, 4to. *Neapoli*, 1699

Nature, 1894–95, 4to. *London*, 1894–95

Niceron, J. F., Thaumaturgus opticus . . . pars prima, fol. *Lutetiæ Parisiorum*, 1646

Olbers, W., Sein Leben und seine Werke; herausgegeben von C. Schilling. Band i., 8vo. *Berlin*, 1894

Parker, G. W., Elements of Astronomy, 8vo. *London*, 1894

Pfautzius, Christoph., et C. Saalbach, Eclipsin Terræ [Inaugural Dissertation], 4to. *Lipsiæ*, 1674

Philosophical Magazine, 1894–95, 8vo. *London*, 1894–95

Popular Astronomy, 1894–95, 8vo. *Northfield, Minn.*, 1894–95

Rasch, J., Cometen Buech. Von dem newen Stern des 73 unnd von den Cometen des 77 unnd 81 Jars, auch von allen anderen Cometen unnd newen Sternerscheinungen, 4to. *München* [cir. 1582]

Scheiner, J. A., A Treatise on astronomical spectroscopy; being a translation of Die Spectralanalyse der Gestirne, translated, revised, and enlarged by E. B. Frost, 8vo. *Boston*, 1894

S[chwatz], C. G., Mémoire explicatif sur la sphère Caucasienne, et spécialement sur le Zodiaque, 4to. *Paris*, 1813

Wislicenus, W. F., Astronomische Chronologie: ein Hülfsbuch für Historiker, Archäologen und Astronomen 8vo. *Leipzig*, 1895

Woodhouse, R., A treatise on plane and spherical trigonometry, 2nd edition, 8vo. *Cambridge*, 1813

Zeitschrift für Instrumentenkunde, 1894–95, 4to. *Berlin*, 1894–95

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LV. No. 9. SUPPLEMENTARY NUMBER.

INVITATION OF LADIES TO THE ORDINARY MEETINGS OF THE SOCIETY.

The attention of Fellows is called to the fact that Ladies are only admitted to the Ordinary Evening Meetings of the Society by special invitation of the President, sanctioned by the Council. The invitations are issued at the commencement of each Session.

The present number of the *Monthly Notices* being the last of Vol. LV., Subscribers (not Fellows) are requested to take notice that the subscription for Vol. LVI. (10*s*., including postage) has now become due, and should be forwarded to the Assistant Secretary, Mr. W. H. Wesley, Burlington House, London, W., on or before the 2nd of December next; otherwise it will be considered that the subscription has not been renewed.

CONTENTS.

Page

Professor T. H. Safford, On the accuracy of the catalogues of declination of standard stars 495

A. M. W. Downing. Comparison of the Sun's longitudes for 1900 computed from Newcomb's Tables of the Sun with those computed from Le Verrier's Tables 514

W. E. Cooke, Description of a mechanical apparatus for computing refraction 515

John Tebbutt, Observations of phenomena of *Jupiter's* satellites with the 8-inch equatorial at Windsor, New South Wales, in the year 1895 517

John Tebbutt, Results of micrometer comparisons of Saturn and *a Virginis* 1895 May 519

A. Marth. Ephemeris for physical observations of *Jupiter*, 1895–96. Concluded 522

A. Marth. Ephemeris of the fifth satellite of *Jupiter*, 1895–96 . . . 533

A. Marth. Data for computing the positions of the satellites of *Jupiter*, 1895–96 536

Errata 521, 544

Index 545

List of presents received during the Session of 1894–95, and of books purchased with the Turner and Horrox Fund during the same period.

Printed by SPOTTISWOODE & Co., New-street Square, London; and Published at the Apartments of the Society, October 1895.